PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXIII. JUNE, 1894. No. 145.

TABLE OF CONTENTS.

	PAGE
Stated Meeting, April 6, 1894	159
Stated Meeting, April 20, 1894	160
The Secret of the Brownian Movements. *By R. Meade Bache*	163
Obituary Notice of Thomas Mutter Cleeman (with one plate). *By Frederick Prime*	177
The Dynamics of Boxing. *By R. Meade Bache*	179
Obituary Notice of George de Benneville Keim (with one plate). *By D. G. Brinton, M.D.*	187
Some New Red Horizons (with three plates). *By Benjamin Smith Lyman*	192
Remarks on Mr. Lyman's Paper. *By Dr. Persifor Frazer*	216
On the Lungs of the Ophidia (with six plates). *By Prof. E. D. Cope*	217
A Comparative Study of the Chemical Behavior of Pyrite and Marcasite (with two plates). *By Amos Peaslee Brown*	225
Notes on the Osteology of Agriochœrus Leidy (Artionyx O. and W.). *By W. B. Scott*	243
Three New Methods for the Detection of Forgery. *By Dr. Persifor Frazer*	251
Stated Meeting, May 4, 1894	253
Stated Meeting, May 18, 1894	256

☞ It is requested that the receipt of this number be acknowledged.

☞ In order to secure prompt attention it is requested that all correspondence be addressed simply "To the Secretaries of the American Philosophical Society, 104 S. Fifth St., Philadelphia."

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EXTRACT FROM THE LAWS.

THE HENRY M. PHILLIPS PRIZE ESSAY FUND.

Miss Emily Phillips, of Philadelphia, a sister of Hon. Henry M. Phillips, deceased, presented to the American Philosophical Society, held at Philadelphia for Promoting Useful Knowledge, the sum of five thousand dollars for the establishment and endowment of a Prize Fund, in memory of her deceased brother, who was an honored member of the Society. The Society accepted the gift and agreed to make suitable rules and regulations to carry out the wishes of the donor, and to discharge the duties confided to it. In furtherance whereof, the following rules and regulations were adopted by the Society:

First. The Prize Endowment Fund shall be called the "Henry M. Phillips Prize Essay Fund."

Second. The money constituting the Endowment Fund, *viz.*, five thousand dollars, shall be invested by the Society in such securities as may be recognized by the laws of Pennsylvania, as proper for the investment of trust funds, and the evidences of such investment shall be made in the name of the Society as Trustee of the Henry M. Phillips Prize Essay Fund.

Third. The income arising from such investment shall be appropriated as follows:

(*a*) To making public advertisement of the prize and the sum or amount in United States gold coin, and the terms on which it shall be awarded.

(*b*) To the payment of such prize or prizes as may from time to time be awarded by the Society for the best essay of real merit on

Received *of the American Philosophical Society, Proceedings No. 145.*

Name,.....

Address,.....

N. B.—Please detach this page when signed, and return, prepaid, to the Secretaries.

PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA FOR PROMOTING USEFUL KNOWLEDGE.

VOL. XXXIII. JUNE, 1894. No. 145.

Stated Meeting, April 6, 1894.

Vice-President KENDALL in the Chair.

Minutes of last meeting read.

Correspondence was submitted as follows:

Letter accepting membership from Dr. Isaac Roberts, Starfield, Crowborough, Sussex, England.

Circular letter from the Directeur of the Direction Générale de Statistique, of the Province of Buenos Ayres, announcing his appointment to that office.

Accessions to the Library were reported from Mr. Edward Counsel, Melbourne, Australia; Mr. N. A. Cobb, Sydney, Australia; Bataafsch Genootschap, Rotterdam, Netherlands; K. K. Naturhistorische Hofmuseum, Vienna, Austria; Gesellschaft für Erdkunde, Deutsche Seewarte, Berlin, Prussia; K. Gesellschaft der Wissenschaften, Göttingen, Prussia; Würtembergische Kommission für Landesgeschichte, Stuttgart; R. Istituto Lombardo, Milan, Italy; Società Italiana delle Scienze, Naples, Italy; R. Accademia delle Scienze, Turin, Italy; Académie des Sciences, etc., Angers, France; Académie N. des Sciences, etc., Caen, France; Société des Sciences Naturelles et Archéologiques de la Creuse, Guéret, France; Dr. P. Topinard, Paris, France; Société des Antiquaires de la Morinie, Saint-Omer, France; Historical Society, Dr. Hugh

Hamilton, New York, N. Y.; University of Pennsylvania, Dr. William F. Norris, Philadelphia; U. S. Naval Institute, Annapolis, Md.; Smithsonian Institution, Bureau of Education, U. S. Coast and Geodetic Survey, Washington, D. C.; Director of the Michigan Mining School, Lansing; Dr. Jesus Diaz de Leon, Aguascalientes, Mexico.

The following deaths were announced:

Dr. E. Brown-Sequard (Paris, France), born 1818, died April 2, 1894.

Sir P. Cunliffe Owen (London, Eng.), born June 8, 1828, died March 23, 1894.

Hon. Washington Townsend (West Chester, Pa.), died March 18, 1894, æt. 82.

Obituary notice of Thomas M. Cleemann was read by Mr. Prime.

Prof. Cope made a communication on some points of the anatomy of the Ophidia, especially regarding the lungs.

Mr. Lyman offered for the Proceedings a map of the New Red, New Jersey.

Pending nominations Nos. 1273 and 1274, 1276 to 1296, and new nominations Nos. 1297 and 1298 were read.

And the Society was adjourned by the Chairman.

Stated Meeting, April 20, 1894.

Vice-President, Mr. KENDALL in the Chair.

Minutes of meeting, April 6, read.

Correspondence was submitted as follows:

Letters of envoy were received from the K. Meteorologische Institut, Berlin, Prussia; Editors of *Nuovo Cimento*, Pisa, Italy; Musée Guimet, Ministere des Travaux Publics, Paris, France; U. S. Coast and Geodetic Survey, Washington, D. C.

Letters of acknowledgment were received from the Bibliothèque de l'Université Royale, Lund, Sweden (140, 141); K. D. Videnskabernes Selskab, Copenhagen, Denmark (Trans., xvii, 3, xviii, 1; Proc., 141); K. Zoologisch Genootschap "Natura Artis Magistra," Amsterdam, Netherlands (142); K. Zoologisch-Botanische Genootschap, 's Gravenhage, Netherlands (142); Kolonial Museum, Fondation de P. Teyler van der Hulst, Haarlem, Netherlands (142); Prof. G. Tschermak, Vienna, Austria (140, 141); K. Gesellschaft der Wissenschaften, Göttingen, Prussia (141); Observatorio Astronomico della R. Università, Turin, Italy (141); Société d'Anthropologie, Paris, France (140, 141); U. S. Naval Observatory, Washington, D. C. (142); Society of Natural History, Cincinnati, O. (142); Historical Society of Southern California, Los Angeles (96–142, and Catalogue, Parts i–iv); Kansas State Historical Society, Topeka (142); Observatoire Météorologique Central de Mexico, Mexico (140–142, and Catalogue, Parts i–iii); Bishop Crescenzio Carrello Ancora, Mirida, Yucatan, Mexico (142).

Accessions to the Library were reported from the Exhibition Trustees, Melbourne, Australia; Lund University, Lund, Sweden; Academie R. des Sciences, etc., Copenhagen, Denmark; Akademie der Wissenschaften, Physikalische Gesellschaft, Berlin, Prussia; Bath and West of England, etc., Society, Bath, Eng.; Philosophical Society, Cambridge, Eng.; Society of Antiquaries, London, Eng.; Amer. Academy of Arts and Sciences, Massachusetts Historical Society, Dr. Samuel A. Green, Boston, Mass.; Public Library, Salem, Mass.; Tufts College, Mass.; Academy of Sciences, New York, N. Y.; Dr. D. Jayne & Son, Philadelphia; Enoch Pratt Free Library, Baltimore, Md.; Elisha Mitchell Scientific Society, Chapel Hill, N. C.; Society of Natural History, Cincinnati, O.; Mr. S. Waterhouse, St. Louis, Mo.; Agricultural Experiment Stations, Orono, Me., Burlington, Vt., Amherst, Mass., Storrs, Conn., Blacksburg, Va., Columbia, Mo.

Announcement of death:

Dr. William V. Keating, Philadelphia, April 18, 1894, æt. 71.

On motion, the President was authorized to appoint a suitable person to prepare the usual obituary notice.

Mr. Price offered the following:

Resolved, That a Committee of three members of the Society be appointed to confer with the representatives of other societies and organizations, with reference to a public dinner which it has been proposed to give the Hon. Frederick Fraley, the President of this Society, on the 28th day of May, the ninetieth anniversary of his birth.

The following Committee was appointed: Messrs. Price, Vaux and Dr. Brinton.

Mr. Bache read an article explanatory of the Brownian movements. Dr. Brinton made some remarks on the subject.

Pending nominations 1273, 1274, 1276 to 1298, and new nominations 1299 and 1300 were read.

Mr. Prime offered the following resolution, which was seconded by Dr. Brinton:

Resolved, That a Committee of five members be appointed by the President to take into consideration the state of the Society, and to report whether any, and if any, what measures it may be expedient to take for increasing the resident membership of the Society, and promoting its usefulness; and whether in effectuating these purposes it may be necessary to amend the existing laws and regulations.

The matter was discussed by Messrs. Prime, Brinton, Price, Horn and Lyman.

On motion, the resolution was adopted.

The President subsequently appointed the following Committee:

Frederick Prime, *Chairman*, J. Sergeant Price, George H. Horn, William P. Tatham, J. G. Rosengarten.

And the Society was adjourned.

The Secret of the Brownian Movements.

By R. Meade Bache.

(*Read before the American Philosophical Society, April 20, 1894.*)

We first hear systematically of molecular movement, as a thing directly visible, from the writings of the distinguished botanist, Dr. Robert Brown, embodied in a paper entitled, "A Brief Account of Microscopical Observations, Made in the Months of June, July, and August, 1827, On the Particles Contained in the Pollen of Plants; and On the General Existence of Active Molecules in Organic and Inorganic Bodies."

Of course we know inferentially, through physics and chemistry, that the particles of bodies move under the influence of various extraneous forces, and we know, too, that, in the case of matter in a gaseous form, they move also under the influence of force inherent in their own constitution. But the movements of which I am about to speak relate to the visible behavior of what should be termed inert matter, if that expression were not begging the question of whether or not it has in itself power of motion, and thus deciding it in favor of the view that it has not, but is moved by extraneous force. We must begin, therefore, as is but right, by assuming that it is an open question as to whether or not certain particles, in aqueous suspension, call them molecules or otherwise, as one pleases, organic or inorganic, but not endowed with animal life, are of themselves capable of movement, or are moved by some extraneous force or forces at present unknown. The solid ground of fact from which we start is that, under the conditions mentioned, they do move, for that is undeniable and admitted.

Dr. Brown soon discarded, through disproving in the course of his investigations the surmise which he had made, that the particles of pollen indicated by their motion a mode of function analogous to that of spermatozoids, and rested eventually in the conclusion that particles moving in aqueous solutions are not confined to organic bodies or to their products. He had conducted a series of experiments on finely crushed glass, on simple earths and metals, with many of their combinations, and rocks of all ages, including those in which no organic remains have ever been found. Moving particles presented themselves in each of the constituent

minerals of granite. Even a crushed fragment of the Sphynx gave the same results. He tried substances of both aqueous and igneous origin, travertine, stalactites, lava, obsidian, volcanic ashes, meteoric matter, manganese, nickel, plumbago, bismuth, antimony, arsenic, asbestos, actinolite, tremolite, zeolite, and steatite. He tried particles of wood, living and dead, linen, paper, cotton, silk, wool, hair, and muscular fibre that had been exposed to fire under the blowpipe, douched with water, and submitted to immediate examination. The particles from all these substances exhibited as vivid movement after as before they had been so treated.

Dr. Brown, about twelve months later, went on further to declare, under the head of "Additional Remarks on Active Molecules," that:—"The result of the inquiry at present essentially agrees with that which may be collected from my printed account, and may be here briefly stated in the following terms; namely, that extremely minute particles of solid matter, whether obtained from organic or inorganic substances, when suspended in pure water, or in some other aqueous fluids, exhibit motions for which I am unable to account, and which, from their irregularity and seeming independence, resemble in a remarkable degree the less rapid motions of some of the simplest animalcules of infusions. That the smallest moving particles observed, and which I have termed Active Molecules, appear to be spherical, or nearly so, and to be between 1-20,000 and 1-30,000 of an inch in diameter; and that other particles of considerably greater and various size, and either of similar or of very different figure, also present analogous motions in like circumstances. I have formerly stated my belief that these motions of the particles neither arose from currents in the fluid containing them, nor depended on the intestine motion which may be supposed to accompany its evaporation. These causes of motion, however, either singly or combined with others,—as, the attractions and repulsions among the particles themselves, their unstable equilibrium in the fluid in which they are suspended, their hygrometrical or capillary action, and in some cases the disengagement of volatile matter, or of minute air bubbles,—have been considered by several writers as sufficiently accounting for the appearance. Some of the alleged causes here stated, with others which I have considered it unnecessary to mention, are not likely to be overlooked or to deceive observers of any experience in microscopical research; and the insufficiency of the most important of those enumerated, may, I

think, be satisfactorily shown by means of a very simple experiment." [Dr. Brown here alludes to what he details at considerable length, as to the trituration together of oil and water, so as to secure, in one case, by a large proportion of water to oil, lacunæ of water of various sizes, filled with particles, protected from evaporation by the oil, and in the converse case, by a small proportion of oil to water, to secure minute oil-drops on the surface of the water, some of which drops were not larger than the solid particles in the water.]

These passages from the writings on this subject of so skillful, careful, and conscientious an observer as Dr. Brown was, excite regret that he had not pursued the subject further. He would have found, among other things, a much simpler and more lasting method of excluding air from the drop under observation, than that which he adopted in forming lacunæ of aqueous fluid protected from evaporation by immersion in oil. He would in all probability have discovered the real cause of the motion of organic and inorganic particles in aqueous fluids. But he dropped the subject, perhaps because he was obliged so to do on account of the pressure of other research, when he had obtained some valuable results, leaving his investigations negative as to conclusions. He doubtless began with the supposition, which seems common at first to all investigators of the subject, that evaporation might represent a shock that would move the particles suspended in water; that vibration from mechanical sources might account for the movements; that currents set up in the drop of water by differences of temperature in it or slight differences in the temperature of the air surrounding it, might account for them; or that mutual attractions, derived from gravitation, and inherent in the relative density of the particles themselves, might do so; and he found, as every one else will find who experiments in these directions, that the movements go on independently of currents and independently of heat, generating or not generating currents, independently of light, and in the case where the particles represent an extremely fine division of matter, and are at the same time of low specific gravity, even independently of terrestrial gravitation; and without relation to their specific gravity, with the force of their mutual gravitation entirely masked.

Some of these things Dr. Brown implies that he saw in the course of his investigations; others he could hardly have failed incidentally

to see, but one that I have mentioned, he did not rightly interpret. It was a distinct lapse in his acuteness of observation, that involved in his mention, without perception of its deepest significance, of minute drops of oil, some of them not exceeding the solid particles themselves in size, standing nearly or altogether at rest on the surface of water; the pointing of which fact is very clear, one which, had it been known to me, would have induced me to try oil as well as water among the first instead of among the last of my own experiments, as actually happened in their sequence.

To afford facility for the fullest comprehension of the subject, it becomes proper here to resume the historical tenor of our way with a brief account of some of the views of Herren Wiener, Exner, and Schultze, more recent than those of Dr. Brown. In order to avoid the responsibility for the necessary condensation, I prefer to quote, as follows, from the summary of their views in the *Jahresbericht* of 1867:

"Then Chr. Wiener, from whose account the preceding historical remarks are quoted, instituted microscopic observations of these movements, and came to the conclusion that this trembling, irregular, unsteady motion of solid molecules, which alter their direction in the briefest fraction of time in their zigzag course, has for its basis the continual movements which, by virtue of their molecular constitution, belong to fluids. He learned through his investigations (1) that the movements are not those of infusoria; (2) that the movement is not communicated to the fluid; (3) that the trembling movement is not in any way derived from the varying attraction and collision of the various oscillating molecules with one another; (4) that the movement is not derived from changes of temperature; (5) that, also, the movement is not derived from evaporation. Consequently, there remained to him nothing to ascribe as the cause of the peculiar movements but the property of the fluid itself. This explanation received direct confirmation from Wiener's observation, that the amount of the movement has a certain relation to the size of the molecule. Lately S. Exner has extended the investigations of Wiener. Among the various influences which Exner sought to test with reference to the molecular motion was whether either chemical causes or mechanical ones, such as pressure, vibration, and so forth, could in any way produce an acceleration or a retardation of the effect. Only by exposure to light and heat did the motion become accelerated, and then in such a manner as,

in the case of glycerin, the molecules of which under ordinary conditions show scarcely any, if any movement at all, to exhibit it clearly when warmed up to fifty degrees centigrade of temperature. Exner also examined into the properties of fluids in which solid molecules remain suspended. The results of his investigation resolve themselves into the following points: (1) The liveliness of the molecular movement is heightened by light and heat, and by radiant as well as by conducted heat; (2) one of the consequences of the molecular movement is, that the molecules, in a specifically lighter fluid, not only do not sink to the bottom, but overcome the force of gravitation to such a degree as to spread themselves equally throughout the fluid; (3) the velocity of this scattering is as the intensity of the molecular movements influenced by light and heat. It should be mentioned here that Fr. Schultze had already stated that substances, when most finely divided, especially such as seemed under the microscope to be amorphous, and exhibited the brownian movements, remain suspended in pure water and in many other fluids for days, weeks, and months at a time, so that the fluid containing them presents a cloudy, or at least an opalescent appearance."

The account of the views of Herr Wiener in the *Jahresbericht* makes an important omission. It devotes itself chiefly to reciting what, in his view, does not cause the brownian movements, but does not mention precisely to what he does ascribe them. Herr Wiener says, in the last paragraph of his article, in *Poggendorf's Annalen*, 1863:—"The weight of the preceding conclusion, that one cannot ascribe the trembling movement to any exterior cause, is very greatly added to by the ascertained fact, that the diameter of the similarly moved water masses is so small that it nearly corresponds with the wave-length of red light, and still more closely with that of radiant heat." This passage gives the keynote to his views on the brownian movements. After a most elaborate series of experiments, in which he measured on a micrometrically divided glass slide, with the addition of diagonal lines, and by watch, the range and the time of the movements, he reached his most important conclusion, that, because the dimensions of the aforesaid wave-lengths of light and heat have a certain close correspondence with the diameters of the minutest particles and water masses, they form the moving impulse of the motions of the particles. He pictured to himself that the æther surrounding the particles, being continu-

ous with the æther of space, acts, through the rays of light and heat on the particles and minute water masses, generating in their interaction, as the visible resultant of the forces in play, the movement of the particles in suspension in aqueous solutions. But, if the cause of the movements assigned by Herr Wiener were the true one, the same cause ought to be operative in the case of alcohol and in that of the fixed and volatile oils: but it is not. This conclusion of Herr Wiener's seems to me to be derived from the unsatisfactory fact of a coincidence, of which kind of proof we habitually perceive more than enough to obscure, bewilder, and often to baffle our feeble efforts to penetrate beyond the veil of phenomena, of things as they seem, to the everlasting noumena, things as they are, near the inscrutable throne of nature.

I will not weary my hearers with the recital of the numerous details of my own experiments, the names of the substances that I tried, the modes in which they were treated, the manipulations of various sorts necessary to the prosecution of the work. Every one knows the difficulties that will arise in new investigations, which will themselves suggest the means of countervailing them as the work proceeds. In this particular case one difficulty was to obtain finely enough divided matter in other liquids besides water. It may be interesting to mention that I did not read anything on the subject until my own experiments were nearly finished. By this course I avoided any possible bias expressed or implied in the directions to be pursued and the conclusions to be drawn, and I had ultimately the satisfaction to perceive, as I had often before observed, how, owing to the constitution of the mind, men necessarily follow the same general and often particular track in their procedures. It is not in the course they follow, that they differ much, but in the conclusions which they reach in pursuing what is virtually the same way. Fortunately for me, constrained to be absent for months in the field on geodetic duty, and at all times constantly engaged at my profession, night still lent itself to my slowly accumulated results. That the investigation was most interesting, I need hardly say.

As electric currents have been demonstrated in the human body, I naturally thought that all slight differences of tension between the liquid and particles, or in the liquid itself, might set up electric currents. Therefore I passed the galvanic current through liquids filled with particles, watching them carefully. There was not the slightest

visible effect thereby produced on the movements of the particles. If the movements had been produced by electric currents, then so strong a current as I often passed through a drop of water ought to have left no manifestation of movement possible from the necessarily weak, if actually existing, currents supposed to be actuating the particles. The molecular movement, so-called, is, as described by Herr Wiener, a zigzag one, but that term does not exactly convey the peculiarity of the motion. It is a combination of a jerky, wobbling movement, performed within determinate bounds, entirely irrespective of the sweep of currents in the liquid, or even of the effects in some cases of terrestrial gravity, and in no case seemingly affected by the influence of local gravitation of particle to particle. Taking the vermilion of the sulphide of mercury, as finely divided as it can be made, and turning the microscope at even a slight angle from the vertical, the effect of terrestrial gravity on the particles becomes at once apparent, but taking the carmine, reputedly made of cochineal, the particles are not affected in the slightest degree by terrestrial gravity. Of course it is hardly necessary to say that any solution should be weak, in order to allow the substances under examination to receive the finest division of which each is susceptible as dissolved. The specific gravity of sulphide of mercury is not only much greater than that of cochineal, but additionally it is not susceptible of nearly so minute division as cochineal is. Of all substances that I experimented with, cochineal seemed to be that which is capable of the finest division, and at the same time of the most brilliant illumination. Gamboge, which appears to be the substance of predilection among many persons to experiment with for the brownian movements, offers nothing comparable to the brilliancy and the fineness of particles of carmine derived from cochineal. With a weak aqueous solution of carmine one may see by daylight, on a background of faint blue, and by ordinary artificial light, on a golden one, thousands of tiny particles, bright as sparks of ruby, shimmering and performing their independent evolutions over the field of view.

Just as one sees a boat managed by an unskillful helmsman pursue its erratic way in going about, being taken aback, or heeled over by a flaw of wind, without for a moment attributing its movements to currents or any other cause but the true one, so the constant observer of the brownian movements knows full well that the particles themselves are moving, not being moved by currents or by gravitation

towards the earth or among themselves. He, from the first, recognizes the fact that the smaller the particles are, the more vivid is their movement. He recognizes another, that, although many large particles do not, as masses, move at all, yet the larger masses are all alive, as it were, with smaller ones, seen clearly around their periphery, on the silhouette of which they are seen plying like banks of oars in an ancient trireme. He is struck with and convinced of still another thing, that whereas one might expect to find that all particles would manifest an attraction for each other through gravitation, and that the larger and largest, but all in proportion to their relative size, would attract and absorb the relatively smaller and smallest ones, nothing of the kind occurs, but the smaller, down to the smallest, go their own way, sometimes even touching the largest and bounding off and away as if they do not, as indeed they do not visibly, submit to the force of gravitation. Of course they cannot escape the influence of gravitation, whether terrestrial or among themselves, but the effect of gravitation upon them is masked, in what manner will appear later.

It seemed to me that magnetic earth-waves might affect particles in such delicate suspension as those of which we are speaking, some of which are no greater in diameter than 1-100,000 of an inch, seen under various powers capable of magnifying from 650 to 1300 diameters. Accordingly, I have placed the particular fluid under examination in the lines of force of a permanent magnet, with the magnet on one side and the keeper on the other of the drop of fluid. Concentrating the gaze on individual particles, to observe if their movement were modified, and then on others in succession, and often repeating the experiment, nothing could be observed other than the movements existing before the magnet had been brought into requisition. The only kind of particles susceptible to the influence of the magnet were those of precipitated iron, but iron is always obedient to the magnet.

Heat I applied in various ways, either irregularly or in an endeavor to distribute it as equably as possible on the glass slide on which the particular experiment was made. Mere currents are set up during the adjustment of temperature from radiation. At the same time one can observe and differentiate the motions due to the brownian movements, the motions along currents, and also the motions from terrestrial gravity, if any, exhibited by particles, if

the specific gravity of the substance be great, and the microscope be set at an angle with the vertical.

Cold I also applied, putting the slides with their cover-glasses in a freezing mixture of broken ice and water, and reducing them to a very low temperature. Still the movements went on as apparently unmodified as ever. Herr Exner says, it will be remembered, that glycerin, which under ordinary conditions shows absolutely none, or almost no molecular movement, shows it clearly when warmed up to the temperature of fifty degrees centigrade. In all the finely divided bodies, however, which I examined, there seemed to be no increase or diminution in the intensity of the movements, corresponding with their alternate subjection to heat and cold. There were occasions in which I thought that I observed acceleration from light, but I always ended by imputing it to the force of imagination, and if it were not justly ascribable to that cause, the fact that it could be so ascribed, is proof positive that if, through the influence of light and heat, any intensification of the movements of the particles took place, it must have been very small. Moreover, the evidence is certainly here, to show that even if the movement were intensified by light or heat, that was the only influence that could be ascribed to them, that light and heat could not be deemed the cause of the movement. And lastly, Herr Wiener's micrometric measurements of the range of movement at different temperatures completely bore out this conclusion.

The theory of Herr Wiener, that the movements are due to the action of the red-wave of light and heat is refuted by the single fact that, as I have proved by experiment, one may interpose at pleasure between the source of light or heat and the particles, either a violet glass or a red glass, without being able to observe the slightest alteration in the movements, either as to their range or their velocity. That is to say, red rays may be either partially excluded or selectively admitted, without diminishing or increasing the liveliness of movement. Hence light can have nothing to do with the phenomenon under discussion, and I have just shown, through the citation of the freezing mixture experiment, that heat can have nothing to do with it.

I have reserved to the very last the discussion of the question as to whether or not the shock, if any there be, from evaporation can have anything to do with the movements, although this was a point that entered into my first investigations. I have reserved it to the

last, because its discussion requires more than the brief space which I have devoted to the previous individual results, and because it leads directly to the conclusion that I have finally reached as to the true cause of the movements. I started out with the conception, which it seems is common to every one, that evaporation might be accompanied with a series of minute explosions, which produce shocks that manifest themselves through the mass of an aqueous solution, in the form of minute movements of finely divided matter held in unstable equilibrium by suspension in the fluid, and that these, escaping cognizance from any ordinary observation, might be visible as such, or in their effects, through the instrumentality of high powers of the microscope. I had come to believe long before, from observation and experiment, that no tremors from mechanical agency or any other, except perhaps from evaporation, could produce the peculiar movements known as brownian, and finally it remained to discover if this or any other intrinsic cause were at work that would account for them.

At this point I encountered an obstacle. My high powers of the microscope were both water-immersion lenses. It seemed, therefore, that even when I had had the drop of liquid under observation, sealed beneath a cover-glass, I might have included, by the use of the water-immersion lens itself, an evaporating surface which might have produced the optical illusion of the movement of the particles in suspension. I proceeded, however, with my experiments, upon the assumption that this, as the event proved to be the case, was not true, and meanwhile procured from Vienna a one-fifteenth dry-lens by Reichert, the highest power of dry-lens that he makes.

I had already obtained for high-power lenses a film of liquid thin enough to be observed through all its strata, free of air within the cell, and protected from evaporation by being hermetically sealed. Any ordinary manufactured cell is too deep, and with all precautions taken contains a little air. On the other hand, the mere cover-glass superposed on a glass slide contains too slight a depth of fluid. I made a cell by using gum-shellac traced in a circlet on a glass slide, which cell, when partially dried, is filled to the brim with the liquid to be observed upon, whereupon the cover-glass is pressed into the yielding gum, thereby expressing the contained air with the superfluous liquid, when the product, dried over night, is fit for use on the following evening. One slide, prepared in this manner and filled with a slightly tinted solution of carmine

from cochineal, had been observed upon by me for weeks, with a one-tenth water-immersion lens, and afterwards, upon the arrival of the one-fifteenth dry-lens, was observed upon without showing any variation in the range and vividness of movement of the particles subjected to examination. I have even covered the whole microscope with a pall of thick, black, woolen cloth, so that not a ray of light could enter it, either through the cover-glass or the eye-piece, and then carefully placing the eye close to the eye-piece, have suddenly thrown light upon the cover-glass, when the brownian movement among the particles was perceived in as active play as ever. I have therefore concluded, from all these experiments, that neither heat nor light, nor electricity, nor magnetism, nor mechanical shock, nor finally evaporation, is operative in producing the movements; in a word, that the particles move uninfluenced by these forces. I am therefore constrained to believe, upon the basis of the information that I have obtained in the manner described, that it is not the particles which are moved by their own energy, or moved by any energy directly imparted to them from outside sources, but that it is the fluid that moves them.

If their own energy moves the particles, we should see them at the same time obedient also to the law of gravitation among themselves, manifested as the resultant of whatever forces are in play, whereas, although they must be obedient to the law of gravitation among themselves, its effects, and generally, as well, those of terrestrial gravity, are so masked as not to be at all perceptible. Now, when we consider how minute all of these particles are, and yet that they move apparently unhindered with such constancy and force, it ought to be apparent, I should think, that they have no self-motive power. However erratic the paths of individual particles may be, the likeness among the movements is extraordinary, so almost identical in every case, varying in greatness of range and rapidity only in inverse ratio to the size of the particle, that we cannot conceive of self-actuated particles so behaving; for relative greatness of size in self-actuated particles ought to coincide with relatively greater, not relatively less, energy of movement; whereas, here the case is reversed. But there are other facts that I have observed through experiment, which also prove what I say. In alcohol, and as far as my experiments go, in fixed and volatile oils, the brownian movements are not observable, and yet the microscope plainly reveals that the movements of foreign bodies in all

these is as free as in aqueous solutions, and I think more so. So molecular movements of solid particles in suspension in aqueous fluids must take place perforce of the constant repulsions of the constituent molecules of the particular liquid present—water. The minute drops of oils supernatant on water, some of them no larger than the particles in the water below, observed by Dr. Brown, as he says, to be almost or wholly motionless, so behave because the molecules of water glide by the molecules of a substance for which they have not even the affinity that would compass opposition. Be the globules of oil on water never so small or large, the molecules of the aqueous fluid glide by them. Whether a small or a large globule of oil be the particle itself on water, there is no movement of the particle. Dr. Brown says none, or almost none. I think that he was mistaken, that there is no molecular movement whatever.

Fixed oils have not the same molecular constitution as volatile oils, nor these the same as alcohol, nor either the same as water. Whatever these differences may signify in various behaviors, under varying conditions, one, among the rest, distinguishes water from the rest and all other liquids. Despite its apparent perfect fluidity, the reluctance of its molecules to move among themselves as smoothly as do those of other liquids among themselves is one of its most evident characteristics. We see this exemplified by the way, long since ably demonstrated, in which a wave is built up from ripples, by the way in which the surf breaks along the shore, and in the ease with which a small proportion of oil in contact with water modifies or subdues its energy. Only recently I steered a boat in Boston harbor between two headlands, between which, and far beyond, white-caps covered the surface of the water, surrounding a placid lakelet of a square mile in area, black by contrast to its white-capped margin, over the surface of which lakelet I was soon smoothly gliding; and this change from turbulent to placid waters was wholly due to the merest film of oil from Boston's great sewer discharging its contents three miles away on the lowering tide from the head-house on Moon Island into the current running towards the sea. I am aware, of course, that part of the calmness described was owing to the fact that the oil lessened the friction of the wind on the water. But that was not the only cause of the calming effect produced by the oil. Oil prevents the friction of parts on the surface of water already in agitation, and thereby quiets the wave already risen. The area which I have just described as a

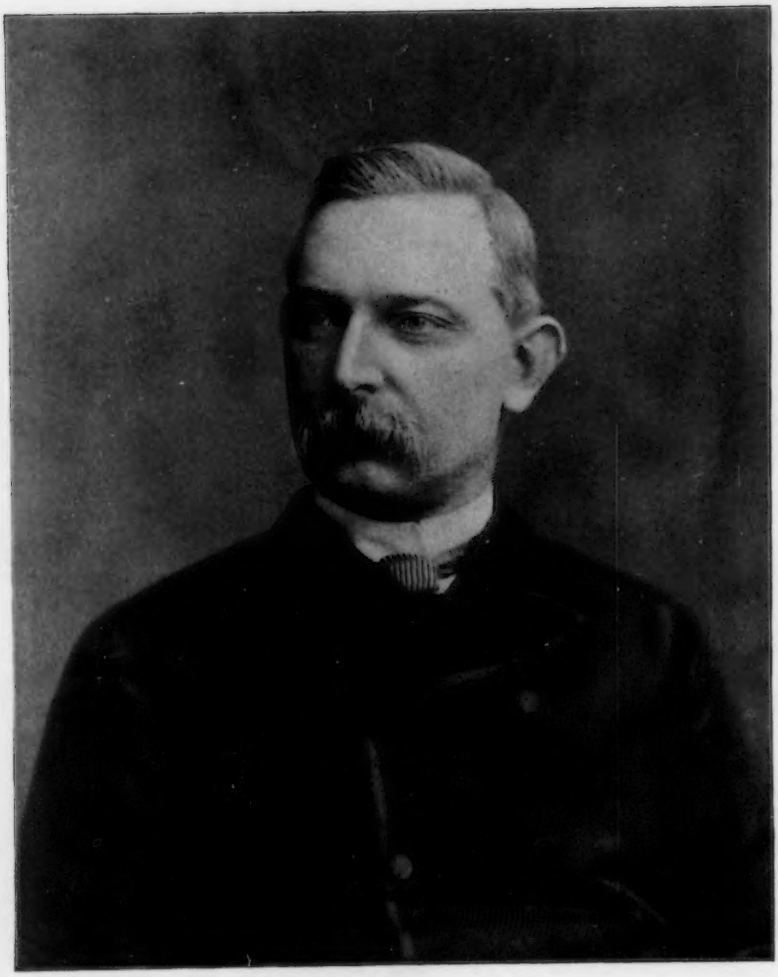
smooth lakelet had been only a short time before my arrival at the place in precisely the same state of agitation as the surrounding waters. The surface is the part where the wave begins to form, and where it receives constant increments, the wind propagating these, and by impact on the growing wave or billow as a whole, forming and propelling it as a mass, despite its tendency in deep water to oscillate freely in the vertical without translation horizontally. It is easily conceivable that, although particles of oil may, as I have stated, experience no sensible friction when in contact with the molecular movements of water, so almost infinitesimal are they in range, yet that oil forming a film over a large surface of water may, through friction, as an enclosing sheath, tend to quiet the water, and thus impair and gradually destroy its ability to continue the massed effect known as a wave, at the place, the surface, where not only is it generated, but where it most effectively tends to preserve its energy of movement.

Thus, it is not only through its weight that water, when set in active motion, becomes so formidable as we know it to be when in angry mood. It is because, besides the momentum with which it can be endowed through its great weight, it lends itself, through its molecular constitution, to the storage of enormous energy and to the yielding up of that energy reluctantly. Assuming the existence of a sea of oil or one of alcohol, and either in a state of turbulence, and moreover eliminating in imagination the difference in weight between these and water, either in comparison with water equally turbulent would gently come to rest.

The difference between Herr Wiener's view and mine is radical. He speaks of the motion common to fluids as the cause of the brownian movements. But such motion, at least as perceptible through the microscope, does not exist, except in water or in some other liquid in which water is, as I have proved by experiment, a considerable constituent. Then Herr Wiener, although accounting for the brownian movements by hypothetical movements common to all fluids, really makes their causation the vibratory effect of rays of light and heat, to which, he thinks, fluids through their constitution lend themselves. I, on the contrary, show that the molecular motion, called brownian, taking place under all conditions imposable, is a property of water and of water only, and that light and heat have naught to do with producing it, although, as I have admitted, they may possibly act in intensifying it. All that I may

claim to have detected is a phenomenon which reverts to the molecular constitution of water, as to which the moving, solid particles in it concerned in the brownian movement have no more to do than has a current-metre to do with the flow of the stream the swiftness of which it measures. We do not deny that a gas may be essentially pure, and therefore homogeneous, a chemical as well as physical entity, and that, nevertheless, its molecules may have repulsions among themselves: on the contrary, we affirm it. Similarly water, recognized, as it is, as a chemical condition, not a mechanical mixture, has, as here demonstrated, repulsions among its molecules.

When I take into account all that I have detailed, and remember also that these moving particles of which we have been speaking, hermetically sealed under glass, as I have them now under cover-glasses, move indefinitely in time, unmodified in range and velocity, through changes of temperature, through light and darkness, through electricity and magnetism, in the presence of every force to which I have been able to subject them, I cannot but think, when I add that these movements are active in proportion to the fineness of subdivision of the particles, that they are caused by the mutual repulsions of the molecules of aqueous fluids. Did I see a relatively large mass moving as vigorously as the most minute one visible to the eye, I should regard this theory as untenable from that single fact alone, because it would be impossible that molecular action should concentrate effect on a relatively great mass; but when I see, as I do, the largest masses remaining unmoved, and descending in the scale, smaller ones, showing the effects of a faint impulse, and descending further still, others exhibiting sluggish movement, until the sight reaches the smallest particle visible, finding in that the most eccentric and vehement movement of any exhibited, I know then that I am looking at a sea where the little waves dash in vain on the impressionless rocks, barely disturb the floating ships and hulks, but twist and swirl and make frantically dance the little cockle-shells of boats wherever they may happen to be upon the surface; and that, in fine, I am witnessing the molecular movement of this sea in its effort to escape into space. The aqueous fluids, finding no release, as under my cover-glasses, the movements would go on forever; finding it in freedom from confinement, they go on until the fluid which is the condition of their manifestation is in a few minutes dissipated in evaporation.



THOMAS MUTTER CLEEMAN.

I must confess that, although every conclusion reached through labor bestowed gives a certain pleasure in legitimate appetite for knowledge gratified, yet this is so far beneath what I had thought might lie hidden under the mystery of the brownian movements, I experience a sense of disappointment. I had thought that this investigation might be one of the paths that lead to the solution of the question whether or not energy is immanent in matter or a thing apart from it. For many years after the beginning of this century nothing fundamental in physics was known beyond the fact that matter is indestructible. It has been learned since, but no longer ago than about fifty years, that energy also is indestructible. It still remains perhaps to be shown that energy is but an emanation and manifestation of matter, reacting on it. Advanced as our knowledge is within a few years as to molecular movement, I had hoped that the investigation of the brownian movements might yield some contribution to molecular theory, and thence lead to a profounder knowledge than we now possess of molecular behavior in the abstract. I am able, however, to claim for the demonstration here no more than that the brownian movements are not the self-movements of finely divided particles in suspension in aqueous solutions, which Herr Wiener had also ascertained, but simply that which he did not ascertain, movements generated by the molecular action of aqueous fluids, instead of being, as he and Herr Exner also thought, in differing form, phenomena due to light and heat. Perhaps even this moderate conclusion may be disputed, but it remains to be disproved.

Obituary Notice of Thomas Mutter Cleeman.

By Frederick Prime.

(*Read before the American Philosophical Society, April 6, 1894.*)

In the year just past, this Society has been called on to mourn the loss of more than the usual number of its resident members. Of these many were taken in the ripeness of their years with their life's work accomplished; some, however, were still in the full vigor of manhood, with apparently a long career still before them. To the latter class belonged the subject of this sketch.

Thomas Mutter Cleeman was born in Philadelphia, July 31, 1843. In

his youth he attended the school of Mr. Gregory in this city, where he formed many of the warm and close friendships which continued throughout his life. Entering the University of Pennsylvania in his sixteenth year, he graduated in the class of 1862; and whilst there developed that marked fondness for mathematical studies which clung to him through life. On leaving the University he entered, as a student, the Rensselaer Polytechnic Institute at Troy, N. Y., graduating in 1865. His standing there was a high one, and on graduating he made an address at the Commencement.

His first active work was as Assistant Engineer on the Allegheny Valley Railroad and on the Pennsylvania Railroad, being under Mr. W. H. Wilson, then Chief Engineer, and closely associated in the work of Mr. Joseph M. Wilson.

His intimate friend, Mr. Walton W. Evans, the eminent engineer, well-known for the high order of his work in South America, sent him to Peru in 1871, to supervise the erection of the first viaduct on the Verrugas Railroad. Being attacked with the Verrugas fever soon after his arrival, which lasted for several months, he was unable to work on the bridge. On his recovery he was appointed Division Engineer of the Callao, Lima and Oroya Railroad, where he remained for some years.

On relinquishing his position in 1874 he returned to this country, but was again sent by Mr. Evans to South America in 1875 as Engineer of the Southern Railroad of Chile.

In the interval between his two first visits to South America he was appointed Principal Assistant Engineer of the Main Building of the Centennial Exhibition in Philadelphia. Whilst filling this position he designed the ingenious construction of trusses, forming a central open space, clear of rods, at the junction of the nave and transept of that building.

From 1876 to 1879 he was Assistant Engineer of the Philadelphia Water Department.

In 1880 he was appointed Resident Engineer of the Richmond and Allegheny Railroad in Virginia.

On relinquishing that position he engaged in a general engineering and consulting practice in Philadelphia.

In the winter of 1892-93 he went to Ecuador as Consulting Engineer on the water works at Guyaquil, at the request of his friend, Mr. A. Millet, who was the engineer and contractor. With this as with everything else he undertook, his interest in the success of the undertaking became very great and the exposure he underwent, in consequence, probably cost him his life. His work there was almost completed and he was looking forward to his return in a few days, so as to spend his Christmas with those he loved so tenderly, when he was stricken down with yellow fever. After an illness of about a week he died, on November 16, 1893, a stranger in a strange land far from those who now so deeply mourn his loss.

Mr. Cleeman was elected a member of this Society October 15, 1885.

He was also a member of the American Society of Civil Engineers; of the Rensselaer Society of Engineers, and of the Engineers' Club of Philadelphia, of which he was a Past President.

In 1892 he delivered a course of lectures on railroads at the Rensselaer Polytechnic Institute, in which he conducted the students through the actual surveys and calculations of the work.

In 1880 he published a work on *Railroad Engineers' Practice*, which has gone through several editions.

Mr. Cleeman was a thoroughly experienced engineer, cautious, intelligent and original in his analysis of theoretical problems, as well as in the execution of engineering work. He was careful to first ascertain that any work he undertook was theoretically correct before carrying it out. His grasp of theoretical subjects was so great that it enabled him to choose wise proximate methods. A friendly critic, he was also a keen one, and his views were generally correct. He did not hesitate to express his opinion on all subjects pertaining to his profession, but never insisted on the acceptance of his view by others; nor had he any of that selfish push and conceited manner which so often meets with undeserved success. A refined, cultured, courtly gentleman, he was entirely unselfish, modest and retiring. His first thought was always of others, never of himself. He was the light of a large circle of friends, as well as of his family.

His death has caused a heartfelt sorrow and sense of loss, not only in the family circle where his sweet nature and gentle manners will always be missed, but amongst the large number of warm and sincere friends, who also loved and honored him

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The Dynamics of Boxing.

By R. Meade Bache.

(*Read before the American Philosophical Society, May 4, 1894.*)

The fact that a certain statement lately appearing in the daily press obtained circulation proves how great the general ignorance of some simple physical laws still is. This statement was to the effect that Sandow, "the strong man," is able to strike a blow of 3000 pounds, could break an arm with its impact, and intends to study boxing so as to defeat Corbett. A few observations, therefore, as to the fundamental laws connected with the subject of the possible degree of the deployment of muscular force by human beings in the act of striking a blow will not be out of place for

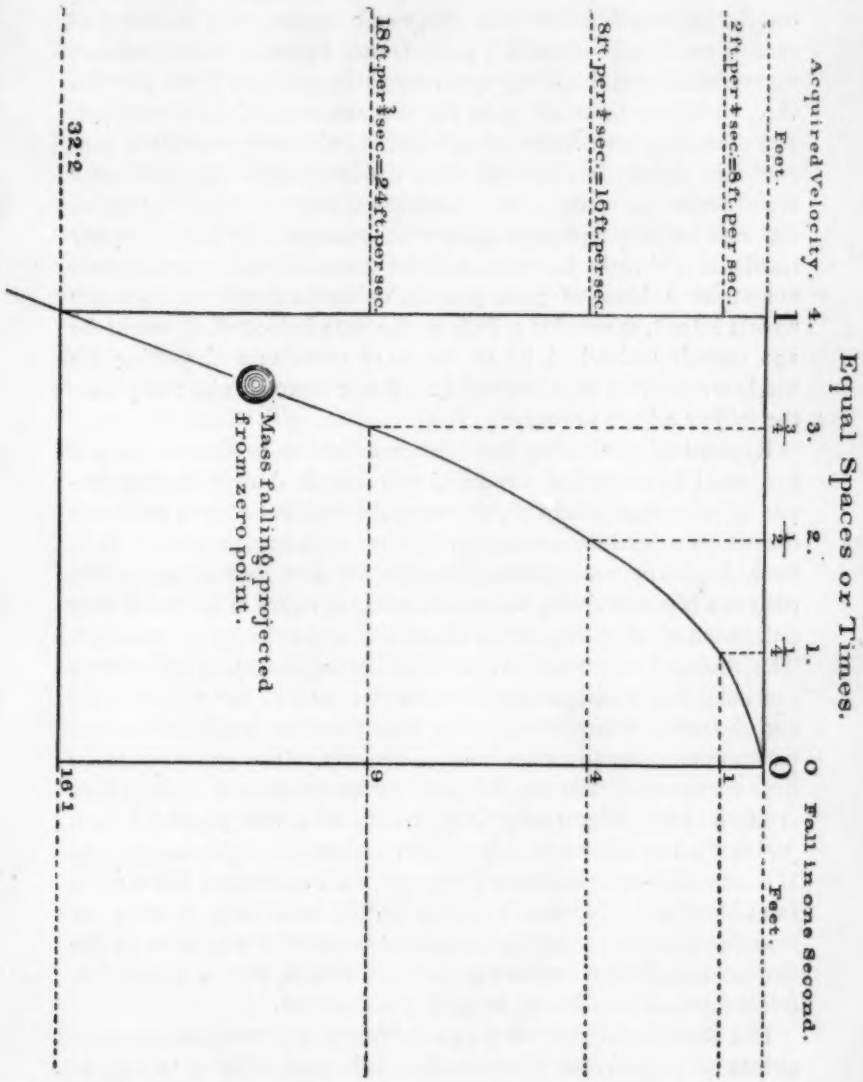
popular instruction. I do not, of course, presume to instruct members of this Society as to these laws, with which they are conversant, but the higher instruction is like head of water, whence the water flows to and filters through lower levels. Besides, beyond the mere restatement here of the laws to which I refer, lies matter with which I think that not even the majority of the members of this Society are conversant. These reasons form, in sum, my explanation for introducing this particular subject to the Society.

The momentum, as you are aware, with which a body, falling freely near the surface of the earth, strikes, varies with the latitude, or otherwise expressed, with the distance of a given place from the centre of the earth, which, owing to the configuration of the earth, corresponds with the latitude. But, for general purposes, and quite sufficiently precise for this, the distance, in the first second, which a free body falls, near the surface of the earth, from a state of rest, is accepted as 16.1 feet, and the velocity which it has acquired by the end of that space and at the termination of that time, as twice 16.1 feet, or 32.2 feet in that second.

The diagram on the blackboard illustrates clearly the effect upon a body moving for one second under the influence of gravity. To understand, then, what follows, it will only be necessary to observe, by referring to the diagram, that the successive spaces traveled by the falling mass represent the squares of intervals, whether of space or time, and also that, although the maximum space traversed in a first second of fall is only 16.1 feet, yet that, correspondingly with the smaller spaces and the inclusive one (all squares of space or time), the acquired velocity doubles continuously, being, instead of 16.1 feet, 32.2 feet in the second, by the time that it has reached the end of the first second of fall. The diagram fully exhibits the law of both relative spaces and relative times concerned in the phenomenon. If the first unit of horizontal space on the diagram, one-fourth, be taken as a unit of time, then its square will represent the value of the corresponding distance of fall. This is 1 foot, with acquired velocity of 8 feet. For successive units of time,—if a mass falls in 1 second, as it does, 16.1 feet, then in 2 seconds it falls 16.1 feet multiplied by 2 squared. It falls in 3 seconds 16.1 feet multiplied by 3 squared, and in 4 seconds 16.1 feet multiplied by 4 squared, and so forth.

Could a soap-bubble move with the velocity of the swiftest cannon-ball, it would injure nothing that it might strike, while the

seemingly almost spent cannon-ball has more than once shorn off human limbs as though they had presented no more obstacle than



thistle-down. Suppose now, that a man weighing 190 pounds (about the maximum weight effective in the ring) should fall, as a

body falling freely near the surface of the earth, for the distance of 16.1 feet. As the moving energy of his mass would be compounded of the mass multiplied by the velocity with which it travels, it would follow that the shock at the end of 16.1 feet (which would take place in a second) would possess the momentum represented by multiplying 190 pounds by 32.2, or 6118 pounds. One, therefore, perceives from the diagram that if, for a weight of 190 pounds, a momentum of only about twice 3000 pounds is generated by gravity in a second, with a velocity *twice as great as a boxer's blow* (as it would be, if the velocity of the boxer's blow at the rate of four feet in a quarter of a second be here correctly rated), it is already demonstrated that a man of 190 pounds could not strike a blow of 3000 pounds, unless he could put his whole weight into it, when, for 4 feet, at the rate indicated, it would be 190 pounds multiplied by 16, or 3040 pounds; and putting his whole weight into it is impossible. But it is worth while to pursue the subject a little further.

Remembering what has just been remarked as to the momentum generated by the fall of a mass of 190 pounds during the first second of time from a state of rest, we must now, in order to make safe comparisons between conditions that are only analogous, not identical, begin by recognizing formally the fact that a man cannot deliver a blow involving the conditions of delivery in a second, over a distance of 16.1 feet, and with an acquired velocity of 32.2 feet. The distance concerned, to say nothing of the other differences, precludes direct comparison between the rate of the man striking and the rate due to gravity. We must therefore institute the comparison and come to a conclusion indirectly. The longest distance over which a tall man can deliver his average blow is about 4 feet. A man with abnormally long reach, like the present boxer, Jackson's, can deliver it over 4.5 feet without changing his footing. If a man delivers it 4 feet in a quarter of a second (and this I think from observation the best boxer can do), he delivers it with the velocity with which gravity would have affected any mass in the first second of time from a state of rest, that is, with a velocity of 8 feet for the half second, or 16 feet per second.

If a boxer strikes four feet in a quarter of a second, of course he strikes at the rate of 8 feet in half a second, that is to say, he strikes with the same velocity as that due to acceleration from gravity during half a second. There is, however, in this case, no ques-

tion of acquired velocity, or what is otherwise known as acceleration, due to terrestrial gravity. I am merely putting the two equals, as derived from different sources of power, in juxtaposition, so as to compare and contrast them with each other, and thus to bring clearly before the mind that it is not likely that any boxer's blow can have a speed essentially greater than that represented by the acceleration due to gravity in half a second, or, in other words, the rate of 16 feet per second. Terrestrial gravity would, as indicated, have nothing to do with the force of the resultant blow. The blow being horizontal, the force of gravity with relation to it would be virtually *nil*. The statement here is limited strictly to the fact that if the boxer can strike 4 feet in a quarter of a second, he can strike that distance with the momentum that would be generated by gravity in one-half of a second, acting on any mass subjected to it from a state of rest.

The fact must be kept constantly in view that mass and velocity combined make momentum. With enormous weight and great slowness, the effect produced is not of the nature of a blow, but that of a push. With great velocity and minute weight, the blow produced is slight. With both great weight and great velocity, the blow becomes tremendous. Here it is well to add that the popular notion of the amount of his weight that a man can put into a push or a blow is highly erroneous. Mechanical engineers, who are continually obliged to make computations for the deployment of the force of pushing on capstan-bars for drawbridges and other places, know that, unless there are cleats on the ground from which the feet can obtain some purchase, from 15 to 20 pounds is about the proper amount to allow for the push of a man working under those conditions. The question therefore remains open in every individual case, unless instrumentally settled, as to what proportion of the mass of the boxer of 190 pounds enters into his blow, and this, with different men, varies as well as the speed. But supposing, for the sake of argument and demonstration, what has already been rejected, that the whole weight of the man enters into the blow, its momentum for 4 feet, at the rate indicated, would be represented by 190 pounds multiplied by 16, or the rate of speed, at the half-second point, due to the force of gravity for a first second, and would be, as already noted, 3040 pounds. A man cannot, however, as already stated, put his whole mass into a blow, because he cannot, by any muscular effort whatsoever, move freely in space. The indispen-

sable condition of his being able to deliver an effective blow is that he shall be, as to his feet, poised on the surface of the earth. So unless, by means of electrical recording apparatus, we determine the speed of a blow, and, by means of a dynamometer, determine the moving energy of it, and deduct one value from the other, we cannot ascertain how much of the effectiveness of a blow is owing to the weight of the human body thrown into it, and how much is derived from a speed which involves the whole person—hand, arm, and trunk.

It would follow, from all the evidence at my command, that if the speed of a blow of four feet be a quarter of a second, a man of even 190 pounds in weight cannot follow up, so as to make effective in his blow, with more than 32 pounds (in round numbers, a sixth of his weight) with velocity equal to free movement of fall of a mass for the first half-second, from a state of rest, above the surface of the earth. Barrett, the late well-known teacher of boxing in Philadelphia, a man of undoubted veracity, as highly esteemed in his day and limited sphere as was, at the beginning of this century, in a more extended one, Gentleman Jackson, of England, Byron's boxing master, once told me as remarkable that he knew a man who could strike 500 pounds. This meant, of course, as tested by a dynamometer. If then, in fine, the time of a boxer's blow be a quarter of a second, the length 4 feet (which would make, as already remarked, the rate the same as that due to the effect of gravity on a mass in the first half second, fallen from a state of rest), and the proportion of his weight accompanying it be 32 pounds, he would strike with the momentum represented by 32 pounds multiplied by 16, or 512 pounds. This momentum, if the reader experienced in boxing will consider the speed here ascribed to the blow of the finest boxer, and the confirmatory evidence derived from the statement of Barrett, would seem to be very near the mark. No one will be likely to maintain, after what has been said, the possibility of striking an effective blow of 4 feet in length in less than a quarter of a second; or that, of the weight of a man of 190 pounds, more than 32 of them can be put into a blow corresponding with the rate of 16 feet per second.

Up to the point we have reached the conclusions drawn were partly dependent upon an estimated velocity of blow, derived from observation, not experiment. But a friend having reminded me that, among Mr. Muybridge's series of photographs of movements of man and

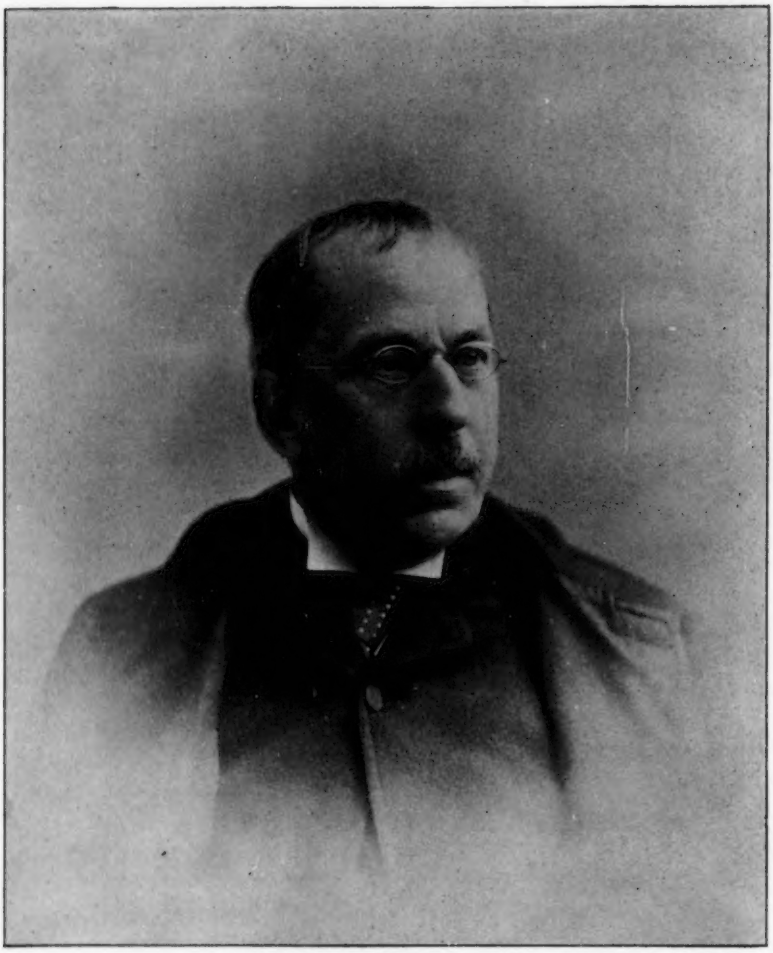
the lower animals is one illustrating the speed of a blow, the examination of it which has followed has led to a remarkable confirmation of the preceding estimate of speed. Plate No. 333 of the Muybridge series represents the phases of a knockdown blow, including the effects, until the person struck is prone on his back on a mattress. The intervals between the photographic phases is ninety-six one-thousandths of a second. Three successive phase-pictures, thus virtually taken one-tenth of a second apart, represent the blow from start to finish. In the first, the striking arm is drawn back and starting from its point of departure. In the second, the arm is seen projecting about half way between the boxing opponents. In the third and last phase of the blow the fist of the striker lands on his opponent. The interval between the first and second phase having been virtually one-tenth of a second, and that between the second and third also one-tenth of a second, the blow was therefore delivered in virtually one-fifth of a second. Measurements on the pictures giving the successive phases show that the length of the blow from start to finish was 38 inches. Here we have the rate of 38 inches in one-fifth of a second. We have previously used the estimated rate of 48 inches in one-fourth of a second. The data derived, on the one hand, from observation, and that, on the other, from experiment, coincide within a small fraction—within half an inch.

It is open to observation that boxers who make their living by ring-fighting carefully conceal from the public, knowledge of the momentum with which they can strike, although this could be easily and safely obtained, and probably often is, with the glove and dynamometer. In the ring, as in many other instances in which all seems physical to the casual observer, moral elements enter. The dangerousness of the man whose exact moving energy of blow is known, is to a certain extent discounted, so potent is the imagination in the affairs of men. Professional fighters know, as well as every one else does, that everything unknown seems magnificent.

The element of quickness in a boxer, in addition to courage, skill, strength, weight, and endurance is indispensable. In the case of such men as Sandow, muscles have been trained by work so ponderous that they do not respond to the will for elastic, quick movements. Men like him cannot put the same speed into their blows as can men trained as Corbett has been, nor can they put the weight of their bodies as effectively into their blows as men can who have

been trained for strong, lithe movements. Consequently, the blows of such men, no matter how heavy the men are, have less power than those of men trained as boxers. So far from Sandow's being able in the ring with Corbett to break his arm or otherwise disable him, he would probably not hit Corbett a single blow, or if he did, not one that would have the effectiveness of his opponent's, because it would lack the speed and accompanying weight thrown into his by a boxer endowed with a rare combination of height, strength, weight, and reach, supplemented by agility marvelous for a large man, trained by life-practice to highest excellence within his sphere, and all crowned by the habits which promote endurance.

We should rejoice that we live in an age remote from the false sentiment of some former times, an age of revived physical culture, when it is possible to bestow undisguised admiration on physical excellence of any kind, in its sphere as fine as moral worth, of which it is in some subtle way even now partially emblematical, to become, mayhap, in the course of time, through more general observance of the laws of nature, wholly identified with it, and indivisible in attributes. Within our own time is observable a great advance in obedience to those laws. It should be evident that the almost universal admiration for physical development and prowess is not wholly derived from the combative quality of mankind, but has its root deeper in human nature, in the general interest in the health and welfare of the species. If, however, it be needed that the combative manifestation of nature be sustained on moral grounds, then is its defense easy. Inasmuch as the present stage of development is conditioned in almost every sphere of animal life on self-defense, self-preservation being still the first law of nature, all teachings which tend to suppress among men any resort to the *ultima ratio* of their kind, tend also to transform their means of defense exclusively into the meaner modes of securing it, into the adoption, to that inevitable end, of cunning and treachery, and the swarm of the meaner vices, sapping the noble elements of their nature, which must go hand and hand and stand or fall together. For my own part, I candidly avow that my observation of life from boyhood onward, derived from personal experience, from history, and from noting racial tendencies in the present era, has led me to believe that, with reprobation and repression of physical force, as potential, and therefore, if need arise, actual, in matter for which law offers no protection, nor ever will or can, must inevitably go various un-



GEORGE DE BENNEVILLE KEIM.

derhandedness in the conduct of life. I firmly believe that those nations which cultivate physical development by countenancing and promoting athletic sports and contests, with due regard to the exclusion of the cowardliness of brutality, will ever possess in their citizens, as compared with those of other nations differently prompted through race, or differently controlled by law or dominant public sentiment, a greater proportion than the others of those inspired by independence of character, honor, and disposition to fairness as between man and man, constituting them relatively the more stalwart lovers and defenders of the right in every form.

Obituary Notice of George de Benneville Keim.

By D. G. Brinton, M.D.

(*Read before the American Philosophical Society, May 4, 1894.*)

Those who have had a reasonably long and intimate knowledge of men must have observed that among the individuals prominent in the active affairs of the day there are two classes—the one, of such as are wholly absorbed in their daily pursuits, whose natures are, to use a simile of Shakespeare's, "subdued to what they work in, like the dyer's hands"—the other, who, however compulsive and harassing their avocations, retain an individual and independent freshness of personality, often strangely in contrast with the requirements of their working hours.

Distinctly to the latter class belonged our late member, George de Benneville Keim; and all who enjoyed his friendship will agree that an appreciation of his career would be imperfect which failed to present these two aspects of his character. I shall begin with that in which he was familiar to the world in general, and then I shall say a few words about him, as he was known to his friends and near associates.

Mr. Keim was a descendant in the sixth generation of Johann Keim, a member of the Society of Friends, who emigrated from the Rhenish Palatinate to the colony of Penn, and settled at Oley, Berks county, in 1704. The grandson of this Quaker emigrant was General George de Benneville Keim, an officer of note in the

war of the Revolution, from whom our late member derived his name. The de Bennevilles were a French Huguenot family who joined the settlement at Oley in the early years of the eighteenth century.

His parents were George M. Keim and Julia C. Mayer. At the time of his birth, the date of which was December 10, 1831, they resided in Reading, Pa. There he received his preliminary education, and later was at school in Georgetown, District of Columbia. At an early age he matriculated at Dickinson College, Carlisle, Pa., where he graduated in 1849, when eighteen years old.

His first intention was to prepare himself as a mining engineer, and with that object in view he removed to Philadelphia and entered the laboratory of Dr. Charles M. Wetherill, where he engaged in the study of chemistry with especial reference to assaying and mineralogical analysis.

Soon, however, his predilection for a more strictly professional life asserted itself, and in the following year, 1850, he returned to Reading, and began reading law in the office of Charles Davis. Two years later he was admitted to the bar, and began practice in the same city.

At that time, the titles to many of the anthracite coal-bearing tracts in Eastern Pennsylvania were by no means clear, and costly and protracted litigation about them occupied the attention of the courts. To these intricate questions Mr. Keim early devoted himself, and rapidly acquired a remarkable familiarity with their confusing details. This special knowledge brought him into contact with many prominent owners and operators, and at the suggestion of some of these he transferred his office to Pottsville, Pa., in the year 1855.

Here he formed a friendship which lasted for many years and materially influenced his after-life. It was with Mr. Franklin B. Gowen, who about that time began the practice of his profession at the Schuylkill county bar. They were closely associated in many important cases, and Mr. Keim's intimate knowledge of most of the valuable titles in the anthracite coal basin soon obtained for him a large and remunerative practice.

When the Presidency of the Philadelphia & Reading Railroad Company became vacant through the resignation of Mr. Charles E. Smith, at the request of the Board of Directors Mr. Gowen provisionally accepted the position. His remarkable abilities, forci-

ble character and brilliant oratory commanded the admiration of all who met him, and it was not long before he was elected definitely President of this important outlet of the anthracite region. His far-reaching plans were soon formulated, and under the name of the Reading Coal and Iron Company a gigantic corporation was created, the object of which was to control, by purchase or lease, practically the whole product of the western, middle and southern anthracite coal fields.

The crucial part of this colossal undertaking—the examination of the numerous and complicated titles—was entrusted to Mr. Keim. The thoroughness with which he performed this herculean task has excited the astonishment and admiration of members of the bar ever since, for although the transfers which he passed covered about ninety thousand acres and involved many millions of dollars, not one acre has been found, the title to which he approved, but that title has, in every instance, been confirmed by the courts in spite of sometimes strenuous litigation. It is doubtful if any other real estate lawyer in the State can approach such a record, either for magnitude of transaction or uniform accuracy of opinion.

These occupations brought him constantly into relation with the affairs of the Reading Railroad and in 1871 he was appointed its General Solicitor. The calls upon his time at the central office became so frequent that, in 1874, he left Pottsville and took up his residence in Philadelphia, which city became his home for the remainder of his life.

The severe depression in business throughout the country which followed the famous crash of 1873 soon made itself felt acutely on the extensive and heavily hypothecated interests of the Reading Railroad and the Coal and Iron Company. Affairs drifted from bad to worse until, in May, 1880, both companies passed into a receivership. Mr. Keim was appointed, *pro tempore*, to that office. This threw an enormous burden of complicated and discouraging business upon him. In this position he continued until January, 1884, when a reconstruction was arranged and Mr. Keim assumed the Presidency of both companies. This phase lasted but a short time, and in June of the same year both companies again passed into the hands of receivers, of whom Mr. Keim was one, and in that condition they remained until January, 1888.

During this trying period Mr. Keim made every effort to sustain the financial integrity of the companies, to guard their disburse-

ments, and to protect the interest of those whose investments were in them. He steadily resisted the pressure brought to bear upon him to authorize foreclosure proceedings, and what was to him probably the most painful of all the sacrifices he was called upon to make, rather than violate his sense of duty to those who had entrusted him with this great responsibility, he renounced the ties of long and closest friendship.

This receivership ended at the beginning of 1888, when Mr. McLeod was elected President of the Reading Railroad and Mr. Keim of the Reading Coal and Iron Company, and a member of the Board of Managers of the Reading Railroad Company. He resigned from both these positions some time before his death, but up to that event was a Director of the Baltimore and Ohio Railroad Company.

Some idea of the magnitude of the business which devolved upon him during his second receivership may be derived from the official statement, that in that period the gross earnings of the companies were about $150,000,000.

For some years before his decease Mr. Keim had been subject to periodical attacks of arthritic disease, which had doubtless left their impress on the arterial walls and predisposed him to apoplectic seizures. He had visited Europe several times in order to avail himself of the benefits of some of the health resorts recommended for such cases. On Saturday, December 16, 1893, while engaged in some business transactions, he was suddenly seized with vertigo and allied symptoms. He was conveyed to his home and prompt aid was summoned, but in vain. The attack was rapidly progressive, and terminated fatally on the morning of Monday, December 18.

In spite of the absorbing nature of his professional duties, Mr. Keim found leisure to read extensively in general literature and to take a broad and real interest in the progress of thought and culture. The history of his native State and country possessed an early and lasting attraction for him. He was elected a member of the Historical Society of Pennsylvania, December 12, 1853, and was chosen Vice-President, May 1, 1876, to which office he was continuously reëlected up to the time of his death. He was Trustee of the endowment fund, to which he was also a liberal contributor, as he was likewise to the other needs of the Society. Though a regular and interested attendant at the meetings, he was not a writer for the Society's publications.

When the Governor of Pennsylvania was requested by the Legislature to appoint a Commission who should select two distinguished Pennsylvanians as subjects of statues to be presented by the State, and placed in the Capitol in Washington, Mr. Keim was one of those entrusted with this delicate decision. The two decided upon were General Peter Muhlenberg and Robert Fulton, and this selection met with the general approval of the people of the State.

Mr. Keim was elected a member of the American Philosophical Society, April 21, 1882. He was frequently present at its meetings, and manifested an active interest in all questions touching its welfare, as well as in many of those of a scientific character brought before its sessions.

Throughout his life he was a lover of books, especially those relating to history and classical English literature. His library was large, and displayed sound judgment and good taste in the selection of its contents. In it, he often sought and always found a welcome relief from the harassing routine of his daily duties.

Professionally, his strength lay in his profound acquaintance with real-estate law and his accurate estimate of the bearings of precedents. He was not a jury lawyer, and he always felt a hesitation in addressing an audience. Although remarkably able in drawing up a lucid and convincing statement, whether in matters of business or purely technical, a certain timidity of temperament prevented him from becoming an orator. In this he was in singular contrast to his partner, Mr. Gowen.

The ennobling inspirations of domestic life were deeply appreciated by Mr. Keim. In early life he married Miss Elizabeth C. Trezevant, only daughter of Dr. Louis C. Trezevant, of South Carolina. His widow and two daughters survived him.

In the calm pleasures of the home circle he delighted to pass the hours when business calls ceased their demands. For this reason, he was less frequently an attendant at public receptions and entertainments than many of his fellow-citizens holding similarly prominent positions.

Throughout his extremely active life and his constant dealing with questions of magnitude and difficulty, Mr. Keim retained the unvarying respect and generally the warm affection of those with whom he was thrown in contact. His characteristics were entire honesty and sincerity, a simplicity of manner which led him to treat all,

PROC. AMER. PHILOS. SOC. XXXIII. 145. Y. PRINTED JUNE 7, 1894.

no matter what their station in life, with equal courtesy, and a clear, sound judgment, which guarded him from the imposition of the fraudulent or the flattery of the interested. To use the expression of one who knew him long and well, Mr. Charlemagne Tower, Jr., "the leading traits of his private character were honor and loyalty." His charities were unostentatious, but large and constant. One of his old friends writes me that he personally knows of several whom Mr. Keim regularly assisted, and who depended on this assistance for much of the comfort of their lives.

While his acquaintances were numbered by thousands, his intimates were few. Although affable and ready of access, it was not at all easy to understand his real nature, nor to approach his inner personality. A peculiar dry humor, an odd candor of expression, foiled the importunate and disarmed the aggressive. Under the appearance of a certain levity of language and manner he baffled those who attempted to transgress the lines which he had drawn around his intimate life. The impression thus created was so different from that usually expected from a man bearing such heavy burdens of responsibility, that it always at first puzzled, if it did not even disappoint, those who knew him but slightly. Behind this outward habit of encounter, however, was a keen, penetrating judgment and a warm, sympathetic nature, fully recognized and appreciated by those who understood the thoroughness of his work and the spirit of his actions. By his death our city lost a distinguished and worthy citizen, his friends one always dear to them, and this Society an estimable and interested member.

Some New Red Horizons.

By Benjamin Smith Lyman.

(*Read before the American Philosophical Society, May 18, 1894.*)

It seems to be worth while to give, at least roughly and in part conjecturally, some idea of the relative geological position of the different horizons from which fossils have been reported in the so-called American New Red of the eastern part of the United States; for it will thereby be seen how completely and naturally the recently discovered, unexpectedly great, and consequently perhaps not readily accepted, thickness of the New Red in Montgomery county, Pa., harmonizes with all the hitherto

publicly recorded facts in other States. It is true the imperfection of the records will make the present attempt somewhat conjectural, but there is reason to hope that it may keep well within the not wholly unprecedented New Red proportions of two bushels of conjectures to two grains of fully ascertained facts.

Indeed, a great share of what has been voluminously written about the New Red is a mere tissue of conjectures, one part depending on another; but if their connection be traced from one to another it will be clear that the starting-point or original support of them all is the supposed fact superficially and inaccurately observed, and in any case not necessarily conclusive, that the beds in question were at the outset wholly, or almost wholly, of a red color. To be sure, dark-colored beds were seen here and there, but were supposed to have become so by the baking of neighboring exposed or subterranean trap. They were sometimes called "indurated shales," though miles away from any visible trap, and their existence above trap beds, even at some distance, was considered by the most skeptical to be sufficient proof of the intrusive character of the trap.

The next conjecture was that as the beds were all red, or originally so, they must be of one narrow paleontological period, a conjecture favored by the circumstance that fossils were not very numerous, and in fact, as we shall presently see, were confined in great measure to a very limited portion of the whole series. They were all referred indiscriminately to the series merely as a whole, and any diversity of character was overlooked or violently disregarded, and they were by circular reasoning pronounced incapable of belonging to species foreign to that small period. Then it was conjectured that during one narrow paleontological period no very enormous thickness of beds could possibly have accumulated, not more than, say, 3000 or 5000 feet. Then, again, it was conjectured that a series of, at the most, such moderate thickness might well exist in full extent within very small geographical bounds, that in short it was, as has been said of the soul in the human body, "all in every part," and was equally complete in Massachusetts, Connecticut, New Jersey, Pennsylvania and in the Richmond (Va.) coal field. The result of borings in that field occasioned the conjecture that the whole New Red series was only 1500 feet in thickness, even in Pennsylvania; and there was probably surprise at finding a boring could be 3000 feet deep without reaching the bottom of the series at Northampton, Mass., where an unprejudiced tyro in geometry might have predicted the result as not improbable from the exposed dips. The idea, however, had by frequent repetition become fixed, though in reality a mere conjecture, that the total thickness must be small, and hence came the unhesitating rejection of the apparent thickness of 14,000 feet in New Jersey and 55,000 feet in Pennsylvania, in spite of their being in truth arrived at by the only means based on published facts then possible, namely, the estimated average dip and the whole geographical breadth of the series. Although, then, the estimates of the total thickness have varied from 1500 to 55,000 feet with some slight support from

observed facts, it has become a heresy to maintain a thickness different from the still more purely conjectural one of between 3000 and 5000 feet.

Then naturally followed conjectures to account with that moderate thickness for so great a geographical breadth in spite of the known dips. These conjectures have been ingenious and elaborately argued and zealously adhered to, but have one by one been disproved or found to be at best only imperfectly supported by observation. It was thought that the dips might be merely apparent or due to false bedding, deposition on a sloping surface, but the thin-leaved, shaly character of some of the beds and the position of the pebbles, ripple marks and fossil footprints have shown the impossibility of that supposition. It was further conjectured that a series of great parallel longitudinal faults with downthrow constantly in one direction might diminish the thickness to the required extent, but their main support was the very insufficient one that recurring hard beds or parallel hills had a similar red color. A careful consideration of the very much curved strike of the beds in some parts of Pennsylvania and New Jersey shows that no series of parallel great faults would help the matter. Besides, although faults of a few feet or yards are numerous, their direction is not generally longitudinal nor the downthrow uniformly in one direction, and but one great fault has yet been proved to exist, and that only in Pennsylvania and New Jersey, and by no means generally longitudinal.

Conjectures in regard to the trap, supposed to be so important in "indurating" and darkening the New Red, have been, if possible, even more wild and needless. The impression seems generally to have been very strong that every mass of trap must be a dike, and that if it was undeniably interbedded conformably with the shales, it must necessarily be a dike that closely followed the bedding intrusively, no matter how many miles, no matter how soft the shales, no matter how gentle the dip. Sometimes it was preposterously suggested that the trap had occasioned the dip of the shales, both near to it and far away. But, in general, as much advantage as possible was taken of the dip, and the trap supposed to be intruded after the dip had been fully acquired, quite dissociating certain sheets of trap from the age of the New Red sedimentary beds with which all the trap is otherwise so closely connected, and not considering that the dip is even now probably still in process of gradual acquirement, or by occasional small fits and starts (witness the earthquake that was felt only the other day between Lambertville and Flemington, N. J., near the line of the great fault there, and corroborative of the existence of the fault at the place pointed out in a former communication, *Proc. Amer. Philos. Soc.*, Vol. xxxi, p. 314). Yet, as the dip alone is so gentle that a dike following it must have come from many miles' distance to have originated at a depth great enough to be melted, and could hardly be supposed to refrain for so long a space from sometimes breaking across the soft shales by a short cut to the surface, it was imagined that the dike must be nearly vertical at a short distance below the outcrop. Then as

the outcrop was sometimes (for example, in the case of the Palisade trap) more than fifty miles long and "as crooked as a ram's horn," the vertical parts of the dike must, by a marvelous coincidence, have followed the same curves. *Credat Judæus Apella, non ego!* Really, such a belief seems to require an amount of credulity hardly consistent with the modern scientific spirit that hesitates to accept extraordinary explanations where ordinary ones can be found to answer the purpose.

The intrusive conjecture has in fact been in great part rejected, but not hitherto for the Palisade trap, owing to certain observed facts. Still, it seems not at all impossible to account for them, so far as recorded, much more easily and naturally than by the well-nigh supernatural intrusive theory. If the trap appears in one place to cross the sedimentary beds on one side, why may it not be either the side of a dike (for, of course, every overflow must come from a dike somewhere) or merely an evidence of the erosion that took place before the trap overflowed; just as in the case of the "horsebacks" or "rock faults" in coal mines, a small valley in the original coal marsh has been filled with sand or silt? If there be here and there a branch from the bottom of the trap sheet running a short distance into the sedimentary beds, is it not as easily conceivable in the case of an overflow as in that of intrusion? Is it wholly inconceivable that apparently similar branches from the upper surface of a trap overflow sheet into the sedimentary beds might sometimes occur, though none are positively recorded? If there be "indurated shales" above some of the Palisade trap, is it not quite possible, in case of real "induration," that there be another overlying unexposed bed of trap that may have caused it, especially as there is other evidence of interbedded shales? The intrusion conjecture is beset with so many serious difficulties, and the overflow theory with so few, the choice between them seems easy. A vast amount of ingenuity has been expended in trying to reconcile observed facts with the intrusive theory, while immensely less skill is required to show the consistency of the facts with the overflow principle.

The New Red theory, with its conjectures and arguments, both for the trap and the sediments, might well be called the tennis ball of American geologists, or a domestic appliance for mental gymnastics, requiring the minimum of work in the field. Nevertheless the fabric, composed, as we have just seen, in the main wholly of conjectures, based one upon another, without having at the bottom one single substantiated fact, has with the lapse of time become so consolidated, and in its older parts, dating from the early infancy of geology in America, has become so venerated that it may now be considered to be a fully "accepted fable." The hand that attempts to disturb it may probably be regarded as sacrilegious; and arguments against it, though thoroughly founded on facts, will be looked on with more suspicion than new conjectures would be if only consonant with the old baseless ones. But however stubbornly skeptical the public may be in refusing to put faith in the present conjectures, well supported by many observations, instead of the old ones, supported only

by other conjectures, there may yet be found some convenience in the present collation of facts.

New conjectures are still necessary owing to the imperfection of the record of facts outside of Pennsylvania. Although the New Red stretches for hundreds of miles close past some of the most populous parts of America, the probable economic resources never seemed enough to secure its thorough examination and a publication of the results. Even as regards field work it has been a sort of play-ground for geologists rather than a place for thoroughgoing investigation. The State governments to this day, with all their surveys, have never fully provided the means for such work. What little field work has been done, outside of Pennsylvania, has been, in great part, carried out with the exaggerated idea that the geology of a region can be studied out merely by a comparison of the fossils, a far shorter and easier way than the laborious methods of properly geological observation and collation. Such purely paleontological geologizing may be likened at its very best to the rapid hypsometrical work of the aneroid instead of the spirit level; and exclusive dependence on the fossils for geological indications may be compared with confiding in pocket-aneroid work more than in railroad leveling. Furthermore, the paleontologists have not merely altogether neglected to plot numerous dips as an indication of geological structure, but they have not generally thought it worth while to indicate with any sort of precision the beds that have yielded their fossils; though Fontaine has done something of that kind. Wheatley, alone, gave a measured columnar section of about 180 feet, showing clearly the position of his fossils; but he must have been more a geologist than a paleontologist.

The Pennsylvania foundation of the present conjectures is, however, far from conjectural. We are not here entering upon another system of conjectures based on conjectures, but conjectures based at least on facts; and it is to be hoped that the conjectures themselves may prove to have nothing improbable, violent, unnatural or supernatural in them. The unexpectedly great thickness of the New Red in Montgomery and Bucks counties is not conjectural, but has been ascertained by means of much careful, laborious, time-taking work in the field and in the office. Something like one-half of the field was excellently mapped with ten-foot contour lines by the Philadelphia Water Department several years ago, and the rest was roughly contoured expressly for the New Red investigation, and the completed map of it was in part replaced by some United States geological work just then published. Some two thousand dips were plotted on the map. Some two thousand rock exposures, including all the railroad cuts and many long river-side cliffs, were observed, measured roughly and drawn in columnar section to scale. Besides the written description of each rock-layer, some four thousand rock specimens were taken for a more complete understanding and for comparison one with another. A general columnar section was formed by combining the separate ones, computing the intervals between them, having due regard to the dip,

strike and elevation of each exposure, and proceeding from point to point between the nearest ones, so that no essential error could occur from changes of dip or strike in so small a space, and checking occasionally the computation between two distant points over one route by like computations over another route, with the aid sometimes of a comparison of specimens to identify the beds of one observed section with those of another. The topographical features of the country also aided in working out the structure. A complete publication of all the evidence would have been more costly than perhaps at present desirable, and certainly more so than the funds at hand would permit; but it is hoped that the map and cross-sections just now about to be published will be found to contain enough of the facts to be fully convincing of the substantial accuracy of the results. The map was taken in hand by the lithographer over a year ago, and its publication is now almost daily expected, and may take place before this paper can be printed; so that it is not necessary to give here a map or sections of the Pennsylvania portion of the New Red.

The survey, then, has shown that the so-called New Red in Montgomery county is at least some 27,000 feet thick, and that it may be divided into five parts as follows, from above downwards: shales mostly soft and red, at Pottstown and northeastward, about 10,700 feet thick; shales, in great part hard and green, partly blackish, and dark red, at the Perkasie tunnel and near it, with some small traces of coal, about 2000 feet; shales, mostly soft and red, at Lansdale and near it, about 4700 feet; shales, in great part hard, dark or greenish gray, and blackish, partly dark red, at the Gwynedd and Phœnixville tunnels, with traces of coal, about 3500 feet; shales, mostly soft and red, but in small part dark gray, or green, or blackish, with some beds of brown sandstone and of gray sandstone and pebble rock, at Norristown and eastward, about 6100 feet. That is, in the main, two sets of hard dark shales, with soft red shales above and below each; and the lower set of dark shales thicker, blacker and more carbonaceous than the upper one. Nevertheless, the resemblance of the two sets and the fact that, owing to the great fault, both occur twice near the Delaware have occasioned some confusion. It would probably be fruitless to attempt at present outside of Bucks and Montgomery counties to identify more definite horizons than these five great bodies of rock; and it must still be only with more or less of conjecture that even they can be traced into distant States by the maps and descriptions that have been published.

Even in Pennsylvania, outside of those two counties, the published information is too defective for the purpose. If the State government had ever made possible a topographical survey of the whole field, it might probably be comparatively easy now to trace each subdivision by the help of the topography all the way to the Maryland line. As it is, we can only conjecture roughly the horizons of the fossils that have been found. For example, it is very probable that the vertebrate fossils near Emigs-

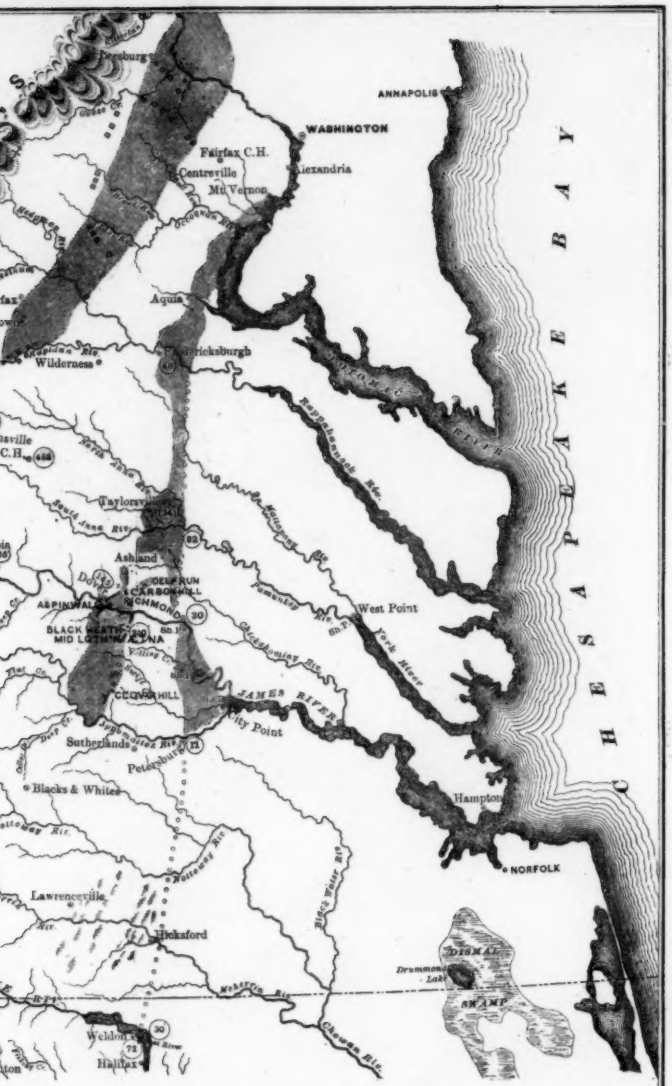
ville, York county, came from the Gwynedd shales; for the place would seem to be not far from the horizon of the coal near Liverpool, close by, that most likely corresponds to the other Pennsylvania traces of coal in the Gwynedd shales and to the more abundant Richmond and North Carolina coals. The fossil algæ of A. Wanner, four miles "eastward" from the Goldsboro fossil footprints, in York county, would also seem to be near the Liverpool coal and likewise in the Gwynedd shales, perhaps higher up than the vertebrate fossils. The footprints and algæ described by A. Wanner as about a mile south of Goldsboro, would then seem likely to be in the Lansdale shales, perhaps towards the top of them.

In Virginia, it is doubtful whether the total New Red thickness is anything like so great as in Pennsylvania; but, according to Fontaine's description (*U. S. Geol. Survey*, Monograph, 1883, vi, 6), there would seem to be representatives there of all five divisions, with a confusion of the two sets of dark shales, on account of their occurring quite disconnectedly one in the eastern and the other in the western areas. The accompanying map, copied from Oswald J. Heinrich's map in the *Transactions of the American Institute of Mining Engineers*, Vol. vi, Pl. v, 1879, with the slight change of omitting certain misleading symbols and adding some names of fossil places, will perhaps sufficiently show the geographical position of the New Red in Virginia and North Carolina.

Fontaine says (p. 6): "The strata of all the areas may be divided into three groups, and this division is most marked in the two eastern coal-bearing areas [the Richmond basin, including the barren Hanover county portion at its northern end, and the Cumberland, or Farmville, basin]. The coal in these occurs in the middle group and is accompanied by a large proportion of black shales. The lowest beds of the two coal-bearing areas are sandstones and shales of a predominant gray color, but with some red strata. . . . . The Cumberland area contains much more of them [the red] than the Richmond area. . . . . The more western areas . . . . show also the threefold grouping of the strata, but in a less marked manner. Where plants and traces of coal occur in them they are found in the middle member. This member contains a comparatively small amount of red beds. The beds are here often gray or greenish gray. The lower group of these areas is usually characterized by the large amount of red strata present and the absence of traces of vegetable matter, except silicified wood. The upper group or member varies in character with the locality, but . . . . the beds are usually barren sandstones and shales, formed of well-sorted components."

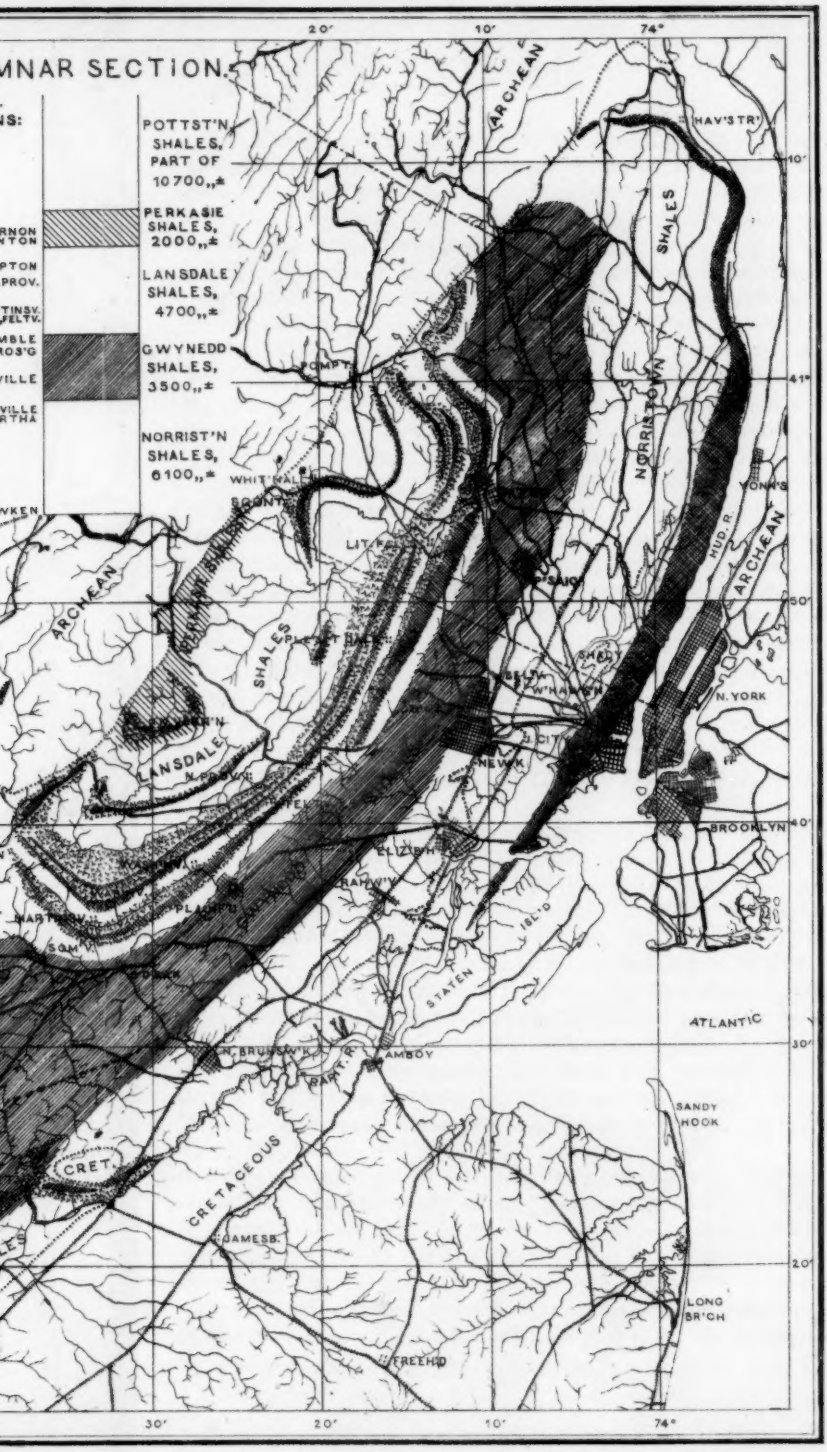
It seems highly probable that the middle member of these western areas, near the Blue Ridge, in Northern Virginia, is the same as the Perkasie shales and that the middle member, at least, of the Richmond and Farmville coal fields corresponds to some part of the Gwynedd and Phœnixville shales, notable in Pennsylvania, even, as containing some thin coal beds. Indeed, it is possible that the whole of the Mesozoic of those two fields may be included in the Gwynedd shales.

A MAP OF THE
MESOZOIC
OF
EASTERN VIRGINIA
AND
NORTHERN NORTH CAROLINA,
COPIED FROM O. J. HEINRICH'S MAP,
TRANS. AM. INST. OF M'G ENG'RS, VOL. VI, PL. V, 1879.
WITH SLIGHT CHANGES BY BENJ. SMITH LYMAN.
APRIL, 1894.
REFERENCES.
Mesozoic Formation.
Undetermined occurrence of Mesozoic.
Boundary of Tertiary Formation.
Outcrop of Coal.
Diorite, Dolerite and Epidosite rocks.
Dip of Strata.
Altitudes above Tide Water.
State Boundary.
Scale, 3 miles to one inch.
N
Fairfax
Georgetown
Wilderness
Barboursville
Charlottesville
Louisa C.H.
Scottsville
Columbia
Farmville
Burkeville
Keysville
Lawrenceville
Danville
Roxboro
Reidsville
Prospect Hill
Oxford
Henderson
Warrenton
Greensboro
Graham
Hillsboro
DURHAM
RALEIGH
Haywood
Blacks & Whites
Sutherland
Lynchburg
Appomattox
Roanoke
Dan River
Yadkin River
Tar River
Neuse River
Catawba River
Allegh'ny Mts
NOTE
FONTAIN
DEEP RIV
SAME H
RIVER C
BELONG
WESTE
TO BE
SHALES
IN THE



NOTE BY B. S. L.— FROM THIS MAP AND PROF. FONTAINE'S ACCOUNT, THE RICHMOND AND THE DEEP RIVER COALS WOULD SEEM TO BE OF THE SAME HORIZON, AND THE FARMVILLE AND DAN RIVER COALS ALSO OF THE SAME; AND ALL TO BELONG TO THE GWYNEDD SHALES. THE NORTH-WESTERN AREAS, NEXT THE BLUE RIDGE, SEEM TO BE LATER, AND TO CONTAIN THE PERKASIE SHALES. THE NORRISTOWN SHALES MAY OCCUR IN THE EASTERNMOST AREAS.

A CONJECTURAL MAP
OF THE
AMERICAN NEW RED
OF
NEW JERSEY AND NEW YORK,
BY
BENJAMIN SMITH LYMAN.
6 APRIL, 1894.
SCALE:— 10 MILES TO AN INCH, OR 1: 633 600.
TRAP RUBBISH.
TRAP IN PLACE.
THE MAP IS BASED ON THE N. JERSEY STATE GEOLOGICAL MAPS AND N. H. DARTON'S, WITH AID FROM THE TOPOGRAPHY. THE GEOLOGICAL STRUCTURE IS ESPECIALLY CONJECTURAL FOR A DOZEN MILES NORTH, WEST AND SOUTH OF SOMERVILLE; BUT ELSEWHERE SEEMS CLEAR, THOUGH THE LIMITS OF THE ROCK GROUPS ARE NOT PRECISELY KNOWN.
CROSS-SECTION
FROM BOONTON TO NEW YORK CITY.
COLUMNAR SE
FOSSIL HORIZONS:
N. VERNON
MILFORD, BOONTON
POMPTON
WHITEHALL, N. PROV.
PLUC'MIN, MARTINSV.
WAR'NV., WASH'NT, FELTV.
TUMBLE
WASH'N'S CROS'G
KLINESVILLE
NEWARK, BELLEVILLE
WILBURTHA
SHADY SIDE
AND WEEHAWKEN
ARCHEAN
PALEOZOIC
AND
ARCHEAN
PHILLIPSB'G
EASTON
PLUCKAMIN
WILPD
FRENCHT.
LANSDALE
NORRISTOWN
SHALES
CRET.
TRENT'N
40°
30°
20°
10°
75°
50°
40°


MNAR SECTION.
POTTST'N SHALES, PART OF 10700,,±
PERKASIE SHALES, 2000,,±
LANSDALE SHALES, 4700,,±
GWYNEDD SHALES, 3500,,±
NORRIST'N SHALES, 6100,,±
ARCHEAN
SHALES
NORRISTOWN
HAV'S TR'T
N. YORK
BROOKLYN
NEWARK
ELIZABTH
RAHWAY
STATEN
ATLANTIC
AMBOY
SANDY HOOK
LONG BR'CH
CRETACEOUS
FREEHD
20'
10'
74°
30'
40'
50'

The Virginia fossils mentioned by Fontaine, forty-two species of plants, all appear to have occurred within the extreme limits of the coal-bearing beds of the middle member of the Richmond and Farmville basins; that is, within a thickness of about 150 feet, and, beyond a doubt, within what corresponds to the Gwynedd shales.

In North Carolina, the composition of the Mesozoic would seem to be very like what it is in Virginia, with three members in the eastern Deep River coal field and three in the western Dan River coal field, each field with its middle member comparatively blackish or greenish and slatelike, with conglomerates and sandstones below, gray, brown and red, and with similar soft and hard red, brown and mottled sandstones above. The description applies more particularly in the Deep River field, but the rocks of the Dan River field are said to be similar and to consist of the same members (see Emmons as reported in *Macfarlane's Coal Regions of America*, pp. 518–520, 526). Moreover, the geographic position of the two fields would seem to make it highly probable that the Deep River rocks would correspond to those of the Richmond coal basin, and Fontaine considers them to do so. The Dan River beds, however, would seem to correspond with those of the Farmville basin, that is, to be the same beds as the Richmond and Deep River beds, but on the western side of an anticlinal. Both the Deep River coals and the Dan River coals would then belong among the Gwynedd shales. It is true, Emmons later considered the lower part of the Deep River darker member to be unconformable and much older, even Permian, and called it the Chatham series; but Fontaine finds nothing in the fossils to confirm such a suspicion.

The North Carolina fossils mentioned by Emmons all come from the Deep River coal field. Only four of them come from what he calls the bituminous slate group of the Chatham series, beds most closely connected with the coals and corresponding, in Fontaine's opinion, to the beds associated with the Richmond coals, the same probably as the middle member of the Richmond coal basin and a part of the Gwynedd shales. The thirty-six other fossil plants all come from higher up, but from what seems to correspond to the middle or upper part of the Gwynedd shales within, say, at most 2000 feet above the coal beds, and below the thick, "red marly sandstones," that may correspond to the upper part of the Gwynedd shales or to the lower part of the Lansdale shales. The North Carolina fossils then all appear in any case to belong to the Gwynedd shales.

As regards the New Red in New Jersey, it was suggested in the previous communication already referred to that possibly a careful study of the topography as set forth in the valuable maps of the New Jersey State Geological Survey might enable the New Red main subdivisions to be traced quite across the State. Later, on actual trial, it did seem possible to accomplish so much rather satisfactorily, and the accompanying map of the New Jersey and New York New Red gives the result. The geo-

logical structure is nearly everywhere quite clear; only within a semicircle for a dozen miles north, west and south of Somerville the indications are not quite certain, and more thorough field work is especially desirable there. Elsewhere, too, the limits of the different subdivisions cannot be supposed to be very precisely marked. In the main, however, the geological structure given in the map seems unquestionable and unmistakably confirmed by the published dips, by the topography, by the trap sheets and by the perfect correspondence and harmony throughout of one part with another.

It is readily seen from the map and its sections that the fossil horizons of Weehawken and Shadyside belong to the lower part of the Norristown shales, and the horizon of Newark and Belleville to the upper part of the same, as indicated also by the close lithological resemblance of the brown building stone of these places to the stone found in Pennsylvania only at that horizon, particularly at the Yardleyville, Newtown and other quarries. The Wilburtha fossils opposite Yardleyville on the Delaware obviously belong to nearly the same horizon.

The Klinesville fossils come clearly from the Gwynedd shales, apparently a little below their middle, and the fossils found near Washington's Crossing and Tumble Station must be from near the top of the same shales. The fossils of Little Falls, Pleasantdale, Feltville, Washingtonville, the Field Copper Mine near Warrenville ("near Plainfield," of Newberry), are all evidently close to one horizon, and that probably in the Lansdale shales near their bottom. The fossils of Martinsville and Pluckamin are perhaps slightly higher up in the same division; those of Whitehall and New Providence apparently at about one horizon slightly above the middle of that division, and those of Pompton Furnace still higher towards the top of the division. The fossils of Boonton would seem to be of about the same horizon as those of Milford in the Perkasie shales, near the bottom; and those of New Vernon slightly higher in the same shales.

It may be noticed that the map represents the trap in place as generally much less extensive than it is commonly given in New Jersey geological maps. It appears to have been customary, both here and in the Connecticut Valley, to infer the existence of solid trap everywhere beneath the surface exposures of trap bowlders and decomposed trap earth. From observations in Pennsylvania, however, it seems far more probable that the solid trap in place is of much narrower dimensions, as often appears where streams have cut their way through hills. It seems quite natural, too, that so hard a rock as the trap generally is should be left by the erosion in the form of hills, standing out prominently above the neighboring spaces that are underlain by the comparatively unresisting sedimentary rocks, chiefly soft shales. It is also quite natural that abundant remains of broken blocks or bowlders and decomposing earth from the trap, so durable is it, should long exist not only beneath the places where its solid bed once lay, but also be carried by the eroding waters to some little

distance in other directions from the outcrops of the solid undisturbed trap. The surprising thing, indeed, is perhaps that the trap hills are not more prominent in the midst of such soft rocks, and that the trap bowlders and gradually decomposing rubbish should not have accumulated to a still greater extent. The explanation, no doubt, is that the trap, with all its hardness and, in human experience, durability, is yet in geological ages comparatively easy of decomposition. At some places it is obviously decomposed almost to incoherence in large masses yet in place, only made visible by railroad cuts. It has therefore seemed advisable to mark the trap as solid, in place, only where it appears to have occasioned hills of some prominence; and, even so, the true extent may have been exaggerated, particularly, perhaps, in the case of the Palisade trap along the Hudson river, where there may well be concealed important beds of shales between separate sheets of trap.

It will be seen from the map that not all of the trap is in overflow sheets; but that, although none of it appears to be in intrusive sheets, there are some dikes cutting across the sedimentary bedding. Surely that is not to be wondered at; and it is not surprising that such cases of dikes should occur more numerously among the older sedimentary beds. For those parts of the field are the ones where the upper beds have been wholly carried away by erosion, and with them whatever overflow sheets may have been supplied by the still remaining dikes.

The map shows that in New Jersey, the same as in Eastern Pennsylvania, the structure of the New Red is much less simple near its northwest border than towards its southeast; and that the old idea of nothing but northwesterly dips is far from correct.

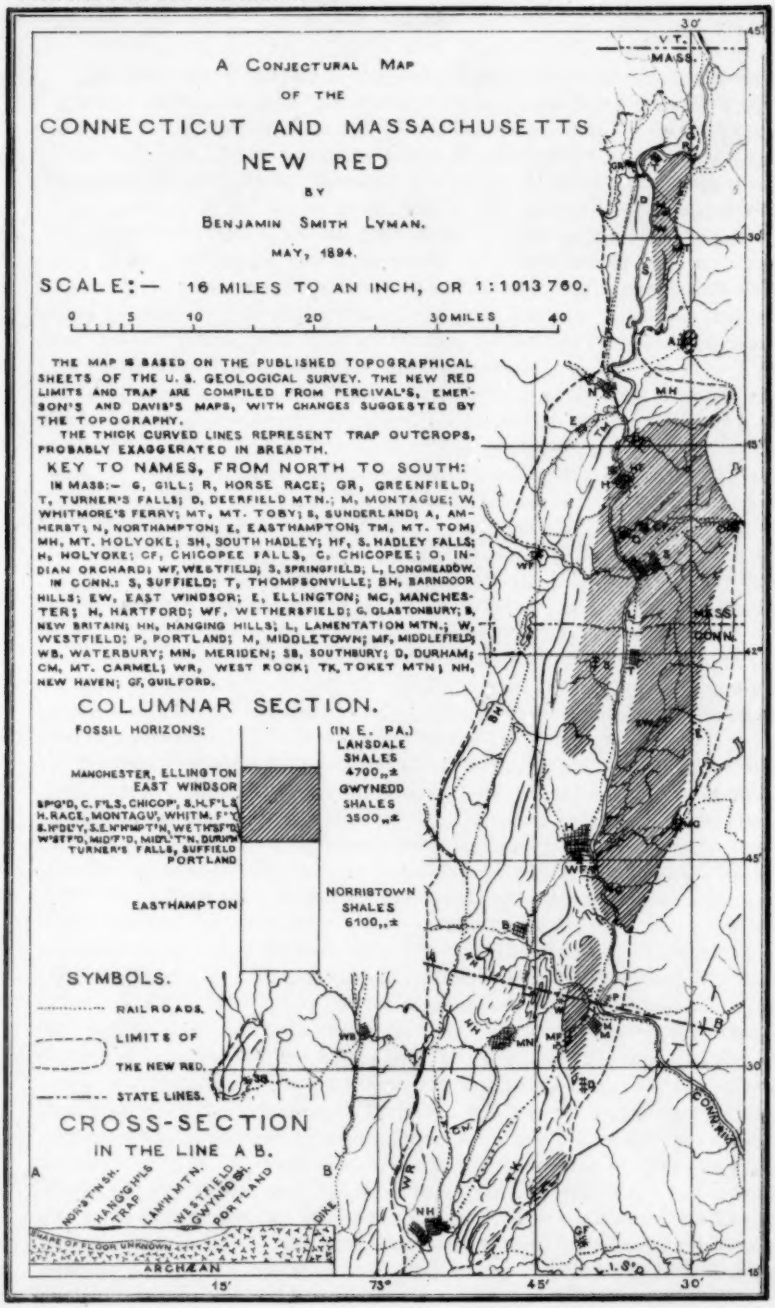
It is noticeable that the thickness of the New Red is much less towards the northeastern end of the field than it is near the Delaware and especially less than in Montgomery county, Pa.; and that the diminution is occasioned by the absence of the upper beds, while the lower ones do not seem to vary very greatly in amount.

The diminution extends into Connecticut in greater degree, and still more so in Massachusetts, as is to be seen in the accompanying map of the New Red there. It is possible that the idea of the very limited paleontological range and thickness of the whole American New Red may have largely originated in the small extent of the Massachusetts and Connecticut series, the earliest to be studied. Another error may perhaps be traced in great part to the same source. The New Red, namely, is persistently called New Red sandstone; though in Eastern Pennsylvania a very small part of the beds, perhaps hardly one-twentieth, are sandstone, and the rest are all shales, or at most sandy shales. In Massachusetts, however, a much larger share of the diminished series would appear to be sandstone; and that fact, together with the time-honored name of the English New Red sandstone was doubtless the cause of giving what is lithologically so inappropriate a name to our American rocks.

The accompanying little map of the Connecticut and Massachusetts

New Red is compiled from the United States Geological Survey topographical sheets so far as published (some parts of the Connecticut field being deficient), and from Percival's geological map of Connecticut, of 1842, and Prof. Emerson's map of the Massachusetts New Red, and Prof. Davis' partial mapping of the Connecticut New Red; but a number of changes have been made according to the indications of the topography. These geological maps gave, for our present purposes, chiefly the outside limits of the New Red and the occurrences of trap. The topography seemed to indicate clearly the necessity of reducing the extent of the trap, in some places very much; and, even as now drawn, the breadth of the trap may be, strictly speaking, somewhat exaggerated, though probably harmlessly so and not inconveniently for better conspicuousness. Notwithstanding the short-sighted niggardliness of the Connecticut government of the time, that did not enable Percival to give in his report more, he says, than "a hasty outline, written mainly from recollection," of his ample field observations, his map has been the great authority for the Connecticut New Red; but it is painful to find that the base itself of the map is extremely inaccurate, not unlike other maps of that date, and even later, in States further west and south. It is probable, also, that he considered every bowlder of trap to indicate that solid trap in place lay immediately below; and consequently many of his trap masses have no corresponding topographical indications. Prof. Davis has already made some just criticism of the map, and, for example, has said: "that the little ridges north of Toket mountain, marked with much detail of curvature on Percival's map, are disappointing when examined on the ground" (*U. S. Geol. Survey*, 7th Ann. Rept., p. 481). It seems highly improbable but that many of the numerous marks for trap on Percival's map cannot represent trap in place. In Eastern Pennsylvania, quite outside the region of glacial drift, exposures of trap in place are very rare, and it is not easy to suppose that they can be anything like so common as his map would seem to indicate in a region heavily covered with drift. It has consequently seemed proper enough to omit many of his smaller trap masses from the present map, wherever there was no topographical feature to corroborate their existence. The lack of the New Haven topographical sheet, not yet published, has perhaps led to the omission of some of the little trap masses that might have been inserted, but they would not be important for the present purpose.

As Prof. Davis has justly remarked, many of Percival's curves in the trap are simply the result of variations in the shape of the surface of the ground, where the outcrop of a bed or sheet, dipping gently, retreats as it sinks into a valley, or advances as it climbs a hill, and such curves may be properly retained. But some of Percival's curves do not seem to have any real support in the topography; and at other places, for example, north of Middletown, the topography gives quite a changed interpretation for the structure. In Massachusetts, too, near Mt. Toby and at the eastern end of Mt. Holyoke the topography seems to require the changes that have been made in the mapping of the trap.


A CONJECTURAL MAP
OF THE
CONNECTICUT AND MASSACHUSETTS
NEW RED
BY
BENJAMIN SMITH LYMAN.
MAY, 1894.
SCALE:— 16 MILES TO AN INCH, OR 1:1013760.
0 5 10 20 30 MILES 40
THE MAP IS BASED ON THE PUBLISHED TOPOGRAPHICAL SHEETS OF THE U. S. GEOLOGICAL SURVEY. THE NEW RED LIMITS AND TRAP ARE COMPILED FROM PERCIVAL'S, EMERSON'S AND DAVIS'S MAPS, WITH CHANGES SUGGESTED BY THE TOPOGRAPHY.
THE THICK CURVED LINES REPRESENT TRAP OUTCROPS, PROBABLY EXAGGERATED IN BREADTH.
KEY TO NAMES, FROM NORTH TO SOUTH:
IN MASS:— G, GILL; R, HORSE RACE; GR, GREENFIELD; T, TURNER'S FALLS; D, DEERFIELD MTN.; M, MONTAGUE; W, WHITMORE'S FERRY; MT, MT. TOBY; S, SUNDERLAND; A, AMHERST; N, NORTHAMPTON; E, EASTHAMPTON; TM, MT. TOM; MH, MT. HOLYOKE; SH, SOUTH HADLEY; HF, S. HADLEY FALLS; H, HOLYOKE; CF, CHICOPEE FALLS, C, CHICOPEE; O, INDIAN ORCHARD; WF, WESTFIELD; S, SPRINGFIELD; L, LONGMEADOW.
IN CONN.: S, SUFFIELD; T, THOMPSONVILLE; BH, BARNDOOR HILLS; EW, EAST WINDSOR; E, ELLINGTON; MC, MANCHESTER; H, HARTFORD; WF, WETHERSFIELD; G, GLASTONBURY; B, NEW BRITAIN; HH, HANGING HILLS; L, LAMENTATION MTN.; W, WESTFIELD; P, PORTLAND; M, MIDDLETOWN; MF, MIDDLEFIELD; WB, WATERBURY; MN, MERIDEN; SB, SOUTHBURY; D, DURHAM; CM, MT. CARMEL; WR, WEST ROCK; TK, TOKET MTN; NH, NEW HAVEN; GF, GUILFORD.
COLUMNAR SECTION.
FOSSIL HORIZONS:
MANCHESTER, ELLINGTON
EAST WINDSOR
SP'G'D, C. F'LS, CHICOP', S.H.F'LS, H. RAGE, MONTAGU', WHITM. F'T, S.H'DLY, S.E.N'MP'TN, WETH'SF'D, W'STF'D, MID'F'D, MIDL'TN, DURH'M, TURNER'S FALLS, SUFFIELD PORTLAND
EASTHAMPTON
(IN E. PA.)
LANSDALE SHALES 4700,,±
GWYNEDD SHALES 3500,,±
NORRISTOWN SHALES 6100,,±
SYMBOLS.
RAILROADS.
LIMITS OF THE NEW RED.
STATE LINES.
CROSS-SECTION
IN THE LINE A B.
A
B
NORTTN'GH.
HANG'GHLS TRAP
LAWN MTN.
WESTFIELD
GWYN'D SH.
PORTLAND
DIAB.
BASE OF FLOOR UNKNOWN
ARCHÆAN
15'
73°
45'
30'
MASS.
CONN.
MH
WF
H
E
S
T
M
W
MF
WB
MN
B
P
D
CM
WR
NH
GF

The map shows, in spite of some uncertainty about the true limits of the different subdivisions of the shales, that the quantity of the New Red that occurs in Connecticut and Massachusetts is probably decidedly less than in Central New Jersey, and that the diminution is still most likely due, not to a proportional thinning of the several subdivisions, but to the total absence of the upper beds, leaving the lower divisions apparently not very different in thickness from what they are in Eastern Pennsylvania. Their thickness, however, needs to be determined with more precision by a closer consideration of the hitherto only scantily published dips. Owing to this evident diminution of the total thickness, it is not necessary to retain, with reversed throws, the series of parallel longitudinal faults that has been proposed for Connecticut.

The geological structure indicated by the map seems very natural and quite in harmony with all the recorded facts and to make no serious fault necessary. The dips near Middletown and Portland and westward would seem to be very gentle, and "occasionally westerly" (J. D. Dana, *Am. Jour. Sci.*, 1891, Vol. xlii, p. 446), so as to justify the indication given of a very shallow basin there, bringing quite naturally the brownstone of the Norristown shales to the surface at Portland. There seems to be another narrower shallow basin or two just west of that one. A very low anticlinal (not a great fault) north of Meriden apparently enables the same brownstone to crop out so far north as Longmeadow, in the southern edge of Massachusetts. The geological structure towards the eastern edge of the New Red, to the dip, seems to be much more complicated than towards the western edge; just as in New Jersey and Pennsylvania it is so along the western edge, to the dip there.

The fossil horizons can be estimated roughly, but probably without very great error. The Easthampton (Mass.) fossil would seem to have come from somewhere near the middle of the Norristown shales; the Portland fossils from the same shales, somewhat nearer their top, and the fossils from the west bank of the Connecticut at the Enfield bridge in Suffield, and those of Turner's Falls again from the same shales, perhaps still closer to the top. The fossils of the small detached area at Southbury also belong probably to those shales, but possibly a little higher. The fossils of Durham, Middlefield, west of Middletown, Westfield (Conn.), Wethersfield, Mittineaque Falls in West Springfield, southeastern Northampton (close above Holyoke), northern South Hadley, Whitmore's Ferry (in Sunderland), Montague and the Horse Race (on Connecticut river in Gill), all seem to belong very closely to one horizon, and that just above the bottom of the Gwynedd shales. The fossils of Chicopee and those between Chicopee and Springfield (possibly those of Springfield, too, if not a little lower) and those of South Hadley Falls would seem to be from the same shales slightly higher up; and the fossils from Chicopee Falls again from the same shales, possibly still slightly higher up; and those from Amherst perhaps yet higher. The fossil bones from East Windsor would appear also to come from the Gwynedd shales, but near their top; and those

from Ellington and Manchester probably from just below their top. Almost all the New Red fossils in these two States, then, seem to have come from the Gwynedd shales, as we have seen is the case in the other States.

It may be worth while to give here lists of all the recorded New Red fossils, arranged according to the different horizons for the sake of easy comparison, beginning at the bottom and proceeding upwards.

Norristown Shales.

Very near the bottom, at Weehawken, N. J. :

Ischypterus Braunii, Newb. (Newb., U. S. Geol. Surv., Mon. xiv, p. 43).
Estheria ovata, Lea (N. J. Geol. Surv. Rep., 1888, pp. 26, 28, 29).
Plants (L. P. Gratacap, Am. Naturalist, xx, p. 245).
Footmarks (do., p. 246).

Likewise very near the bottom, at Shady Side, N. J. :

Estheria ovata, Lea (N. J. G. S. Rep., 1888, pp. 26, 29).
Imperfect remains of fishes (do., pp. 26, 29).

About 3500 feet below the top, below Norristown and at Ft. Washington, Pa. :

Undetermined plants, found a few days ago by Prof. Heilprin's geological class.

About 3000 feet below the top, at Greenville, four miles and a half easterly from Doylestown, Pa. :

Calamitoid plant (Schizoneura planicostata, Font.?), "near Doylestown" (N. Y. Ac. Sci. Trans., 1885, p. 17).
Calamites (?) undetermined (A. P. S. Proc., Vol. xxxiii, p. 7, Feb., 1894).

Towards the top, at the Rocky Hill quarries, a little west of Hartford, Conn.:

Footmarks (Hitchc., Mass. Geol. Rep., 1841, p. 466).

Towards the top, at Easthampton, Mass.:

Clathropteris platyphylla, Brong. (Newb., Mon. xiv, p. 94).
Brontozoum giganteum, E. H. (Suppl. to Ichn., p. 21).
Mollusk allied to Rudistæ Lamk. (?) (Hitchc., Ich., p. 6).

Towards the top, at Wilburtha, N. J.:

Estheria (N. J. G. S. Rep., 1888, p. 29).
Plant remains, imperfect (do., p. 29).

Towards the top, one mile above Prallsville, N. J.:

Estheria (N. J. Geol. Rep., 1888, p. 30).

Near the top, at Newark, N. J.:

Lepidodendron Weltheimianum, Presl. (N. J. G. S. Rep., 1879, p. 26).
Equisetum Meriani (?) (Newb., Mon. xiv, p. 86).
Dioönites longifolius, Emmons (do., p. 92).
Clathropteris platyphylla, Brong. (do., p. 94).
Palissya Braunii, Endl. (doubtful) (do., pp. 13, 94).

Near the top, at Belleville, N. J.:

Lepidodendron Weltheimianum, Presl. (N. J. G. S. Rep., 1879, p. 26).
Bone fragment, well preserved (Cook, N. J. Geol. Rep., 1885, p. 95).

Near the top, at Portland, Conn.:

Dendrophycus triassicus, Newb. (same as Desorii Lesqx., Newb., Mon. xiv, p. 82).
Cunichnoides marsupialoideus, E. H. (Ich., p. 55).
Brontozoum exsertum, E. H. (do., p. 67).
" validum, E. H. (do., p. 68).
" Sillimanium, E. H. (do., p. 69).
Grallator gracillimus, E. H. (?) (do., p. 74).
Isocampe Moodii, E. H. (do., p. 120).
Otozoum Moodii, E. H. (do., p. 125).
Hoplichnus equus, E. H. (do., p. 135).
Impressions of bones apparently ornithic (W. B. Rogers, Bost. Nat. Hist. Soc. Proc., Vol. vii, p. 396).

Near the top, between Wethersfield and Hartford, Conn.:

Plectropterna (Sauroidichnites) minitans, E. H. (1841, p. 482).

Near the top, at Suffield, Conn.:

Alga (Hitchcock, Mass. Geol. Rep., 1841, p. 453).
Plant, possibly a Voltzia (do., p. 451).
Brontozoum (Ornithoidichnites) giganteum, E. H. (do., pp. 466, 485).

Near the top, on Mt. Holyoke, Mass.:

Brontozoum validum, E. H. (Ich., p. 68).

Near the top, at Montague City, one mile south of Turner's Falls, Mass.:

Tridentipes ingens, E. H. (Ich., p. 89).

Near the top, at Turner's Falls, Mass.:

Pachyphyllum simile, Newb. (Newb., Mon. xiv, p. 88).
Pachyphyllum brevifolium (do., p. 89).
" peregrinum, Schimper (Font., U. S. G. Surv., Mon. vi, p. 108).
Actinopteris quadrifoliata, Font. (Font., Mon. vi, p. 121).
Ischypterus ovatus, W. C. R. (Newb., Mon. xiv, p. 27).
Ischypterus tenuiceps, Ag. (do., p. 33).
" parvus, W. C. R. (do., Pl. xiii).
Anomoepus intermedius, E. H. (Sup., p. 2).
" curvatus, E. H. (do., p. 5).
" minimus, E. H. (do., p. 5).
" gracillimus, E. H. (do., p. 6).
Anisopus gracilior, E. H. (do., p. 6).
Brontozoum divaricatum, E. H. (do., p. 7).
Grallator parallelus, E. H. (do., p. 7).
" gracilis, C. H. H. (do., p. 8).
Leptonyx lateralis, E. H. (do., p. 8).
Comptichnus obesus, E. H. (do., p. 9).
Trihamus elegans, E. H. (do., p. 9).
Anticheiropus hamatus, E. H. (do., p. 11).
Harpedactylus crassus, E. H. (do., p. 12).
" gracilior, E. H. (do., p. 12).
Lunula obscura, E. H. (do., p. 17).
Bisulcus undulatus, E. H. (do., pp. 66, 84).
Trisulcus laqueatus, E. H. (do., p. 19).
Grammichnus alpha, E. H. (do., p. 19).
Ampelichnus sulcatus, E. H. (do., p. 19) ("Possibly a plant").
Climacodichnus corrugatus, E. H. (do., p. 20).
Ænigmichnus multiformis, E. H. (do., p. 20).
Brontozoum giganteum, E. H. (Sup., p. 24).
" approximatum, E. H. (Sup., p. 24).
Brontozoum minusculum, E. H. (do., p. 24).
" exsertum, E. H. (do., p. 67).
" Sillimanium, E. H. (do., p. 69).
Brontozoum isodactylum, E. H. (do., p. 70).
Plesiornis mirabilis, E. H. (do., p. 84).
Anamœpus minor, E. H. (Ich., p. 58).
Anisopus Deweyanus, E. H. (Sup., p. 64).
Anisopus gracilis, E. H. (Ich., p. 62).
Amblonyx giganteus, E. H. (do., p. 71).
" Lyellianus, E. H. (do., p. 72).
Grallator cursorius, E. H. (do., p. 73).
" tenuis, E. H. (do., p. 73).
" gracillimus, E. H. (do., p. 74).
" cuneatus, E. H. (do., p. 75).
Platypterna recta, E. H. (do., p. 85).
" varica, E. H. (do., p. 86).
" gracillima, E. H. (do., p. 86).
Tridentipes elegantior, E. H. (do., p. 90).
Corvipes lacertoideus, E. H. (do., p. 98).
Plesiornis quadrupes, E. H. (do., p. 103).
Typopus abnormis, E. H. (do., p. 106).
Plectropterna minitans, E. H. (do., p. 109).
Plectropterna angusta, E. H. (Sup., p. 67).
" lineans, E. H. (do., p. 67).
Harpedactylus gracilis, E. H. (Ich., p. 113).
Xiphopeza triplex, E. H. (do., p. 113).

Antipus bifidus, E. H. (do., p. 116).
Chimæra Barratti, E. H. (do., p. 119).
Isocampe strata, E. H. (do., p. 120).
Otozoum Moodii, E. H. (do., p. 125).
Macropterna vulgaris, E. H. (do., p. 129).
" divaricans, E. H. (do., p. 129).
Shepardia palmipes, E. H. (do., p. 131).
Lagunculipes latus, E. H. (do , p. 132).
Selenichnus falcatus, E. H. (do., p. 133).
" breviusculus, E. H. (do., p. 134).
Hoplichnus poledrus, E. H. (do., p. 136).
Helcura caudata, E. H. (do., p. 141).
Helcura anguinea, E. H. (do., p. 141).
Exocampe arcta, E. H. (do., p. 142).
" ornata, E. H. (do., p. 143).
Harpagopus dubius, E. H. (do., p. 148).
Bifurculipes scolopendroideus, E. H. (do., p. 154).
Hexapodichnus horrens, E. H. (do., p. 158).
Copeza triremis, E. H. (do., p. 159).
Unisulcus Marshi, E. H. (do., p. 160).
" intermedius, E. H. (do., p. 161).
Unisulcus minutus, E. H. (do., p. 161).
Cunicularius retrahens, E. H. (do., p. 163).
" magnus, E. H. (do., p. 164).

Near the top, at the Lily Pond Quarry, on R. Field's farm, in Gill, near Turner's Falls, Mass.:

Acanthichnus alternans, E. H. (Sup., p. 14).
" anguineus, E. H. (do., p. 14).
" trilinearis, E. H. (do., p. 15).
Copeza propinquata, E. H. (do., p. 16).
" punctata, E. H. (do., p. 16).
Conopsoides curtus, E. H. (do., p. 16).
Harpepus capillaris, E H. (do., p. 16).
Sagittarius alternans, E. H. (do., p. 16).
Bisulcus undulatus, E. H. (do., pp. 55, 66, 76.
Brontozoum giganteum, E. H. (do., p. 24).
" approximatum, E. H. (do., p. 24).
Brontozoum minusculum, E. H. (Ich., p. 66).
Brontozoum tuberatum, E. H. (do., p. 66).
Plesiornis mirabilis, E. H.. (do., p. 83).
Anisopus Deweyanus, E. H. (Sup., p. 44).
" gracilis, E. H. (Ich., p. 62).
Grallator formosus, E. H. (do., p. 76).
Argozoum disparidigitatum, E. H. (do., p. 82).
Argozoum paridigitatum, E. H. (do., p. 82).
Tridentipes elegantior, E. H. (do., p. 90).
" uncus, E. H. (do., p. 92).
Gigantitherium caudatum, E. H. (do., p. 95).
Gigantitherium minus, E. H. (do., p. 95).
Hyphepus Fieldi, E. H. (do., p. 97).
Corvipes lacertoideus, E. H. (do., p. 98).
Tarsodactylus caudatus, E. H. (do., p. 99).
Apatichnus circumagens, E. H. (do., p. 100).
Plesiornis quadrupes, E. H. (do., p. 103).
Plesiornis pilulatus, E. H. (do., p. 104).
Orthodactylus floriferus, E. H. (do., p. 114).
" introvergens, E. H. (do., p. 114).
Orthodactylus flexiloquis, E. H. (do., p. 115).
Arachnichnus dehiscens, E. H. (do., p. 117).
Macropterna divaricans, E. H. (do., p. 129).
" gracilipes, E. H. (do., p. 130).
Cheirotheroides pilulatus, E. H. (do., p. 131).
Saltator caudatus, E. H. (do., p. 138).
Chelonoides incedens, E. H. (do., p. 140).
Helcura surgens, E. H. (do., p. 141).
" anguinea, E. H. (do., p. 141).
Exocampe arcta, E. H. (do., p. 142).
Ptilichnus anomalus, E. H. (do., p. 145).
" typographus, E. H. (do., p. 140).
" pectinatus, E. H. (Sup., p. 55).
" hydrodromus, E. H. (Ich., p. 146).
Acanthichnus cursorius, E. H. (do., p. 151).
" saltatorius, E. H. (do., p. 151).
Acanthichnus tardigradus, E. H. (do., p. 151).
Bifurculipes elachistotatus, E H. (do., p. 154).
Hexapodichnus magnus, E. H. (do., p. 158).
Cochlea archimedea, E. H. (do., p. 162).
Halysichnus laqueatus (do., p. 162).
" tardigradus (do., p. 163).

Near the top, on Field's farm, in Gill, near Turner's Falls, Mass.:

Plant, ten feet long (Hitchc., Ichn., p. 170).
Platypterna digitigrada, E. H. (Ich., p. 86).
Apatichnus bellus, E. H. (do., p. 101).
Plectropterna gracilis, E. H. (do., p. 109).
Orthodactylus linearis, E. H. (do., p. 115).
Stenodactylus curvatus, E. H. (do., p. 117).
Saltator bipedatus, E. H. (?) (do., p. 137).
Hamipes didactylus, E. H. (do., p. 150).
Conopsoides larvalis, E. H. (do., p. 152).
Bifurculipes laqueatus, E. H. (do., p. 153).
Bifurculipes tuberculatus, E. H. (do., p. 153).

Grammepus erismatus, E. H. (do., p. 156).
" unordinatus, E. H. (do., p. 156).
Lithographus hieroglyphicus, E H. (do., p. 156).
Lithographus cruscularis, E. H. (do., p. 157).
Cochlichnus anguineus, E. H. (do., p. 161).
Sphaerapus larvalis, E. H. (do., p. 164).

Near the top, in Field's orchard, in Gill, near Turner's Falls, Mass.:

Anisopus gracilis, E. H. (Ich., p. 62).
Stratipes latus, E. H. (do., p. 149).

Near the top, at the quarry near Roswell Field's house, in Gill, Mass.:

Anamoepus major, E. H. (Ich., p. 57).

Probably in the Norristown shales, at Southbury, Conn.:

Tree trunk (Hitchcock, Rep., 1841, p. 456).
Catopterus gracilis, J. H. R. (Newberry, Mon. xiv, p. 55).

Gwynedd Shales.

Towards the bottom at Egypt, N. C.:

Acrostichides Egyptiacus, Emmons (Font., Mon. vi, p. 99).

Towards the bottom, in the Deep River coal field, N. C.:

Acrostichides princeps, Schenk (?) (Font., Mon. vi, p. 99).
Pariostegus myops, Cope (Cope, N. C. Geol. Rep., 1875, App., p. 32).
Dictyocephalus elegans, Leidy (do., p. 32).
Belodon caroliniensis, Emm. (do., p. 34).
" priscus, Leidy (do., p. 34).

Towards the bottom, in the Dan River coal field, N. C.:

Cheirolepis Münsteri, Schimper (?) (Font., Mon. vi, p. 99).
Belodon Leaii, Emm., (Cope, N. C. Geol. Rep., 1875, App., p. 35).
Estheria ovata, Lea (T. R. Jones, Geol. Mag., vii, 1890, p 387).

Towards the bottom, in North Carolina:

Equisetum Rogersi, Schimper (Font., Mon. vi, p. 98).
Sphenozamites Rogersianus, Font. (do., p. 98).

Towards the bottom (?), in Moore county, N. C.:

Belodon Caroliniensis, Emm. (Cope, N. C. Rep., 1875, App., p. 34).
Belodon priscus, Leidy (do., p. 34).

Towards the bottom (?), in Montgomery county, N. C.:

Belodon priscus, Leidy (Cope, N. C. Rep., 1875, App., p. 34).

Towards the bottom (?), in Anson county, N. C.:

Belodon Caroliniensis, Emm. (Cope, N. C. Rep., 1875, App., p. 34).

Towards the bottom, at Clover Hill, Va.:

Schizoneura planicostata, Rogers (Font., Mon. vi, p. 16).
Schizoneura (?), (1 specimen) (do., p. 16).
" Virginiensis, Font. (do., p. 18).
Macrotoeniopteris crassinervis, Feist (do., p. 23).
Acrostichides rhombifolius, Font. (do., p. 32).
Acrostichides rhombifolius, var. rarinervis, Font. (do., p. 33).
Acrostichides microphyllus, Font. (do., p. 34).
Acrostichides densifolius, Font. (do., p. 34).
Mertensides distomus, Font. (do., p. 40).
Asterocarpus Virginiensis, Font. (do., p. 45).
" " var. obtusiloba, Font. (do., p. 46).
Asterocarpus platyrachis, Font. (do., p. 47).
" penticarpa, Font. (do., p. 48).
Cladophlebis ovata, Font. (do., p. 51).

Cladophlebis microphylla, Font. (do., p. 52).
Cladophlebis pseudowhitbiensis, Font (do., p. 52).
Lonchopteris Virginiensis, Font. (do., p. 54).
Clathropteris platyphylla, var. expansa, Saporta, (do., p. 58).
Pseudodanæopsis reticulata, Font. (do., p. 60).
Pseudodanæopsis nervosa, Font. (do., p. 63).
Sagenopteris rhoifolia (?), (do., p. 63).
Dicranopteris, spec. (?), (do., p. 63).
Pterophyllum inæquale, Font. (do., p. 65).
Ctenophyllum truncatum, Font. (do., p. 69).
Ctenophyllum grandifolium, Font. (do , p. 76).
Ctenophyllum giganteum, Font. (do., p. 77).
Podozamites Emmonsi, Font. (do., p. 78).
" tenuistriatus, Rog. (do , p. 79).
Sphenozamites Rogersianus, Font. (do., p. 84).
Baiera multifida, Font. (do., p. 88).
Undetermined cones (do., p. 91).

Towards the bottom, at Midlothian, Va.:

Asterocarpus Virginiensis, Font. (Font., Mon. vi, p. 45).
Pseudodanæopsis reticulata, Font. (do., p. 60).
Pterophyllum affine, Nathorst (do., p. 66).
Ctenophyllum taxinum, L. and H. (do , p. 68).
Podozamites tenuistriatus, Rogers (do., p. 79).

Towards the bottom, at Gowry shaft, near Midlothian, Va.:

Acrostichides limnææfolius, Bunb. (Font., Mon. vi, p. 28).
Acrostichides rhombifolius, Font. (do., p. 32).
Mertensides bullatus, Bunb. (do., p. 39).
Zamiostrobus Virginiensis, Font (do., p. 85).

Towards the bottom, at Black Heath, Va.:

Acrostichides linnææfolius, Bunb. (Font., Mon. vi, p. 28).

Towards the bottom, at Aspinwall shaft, at Manakin, near Dover, Va.:

Equisetum Rogersi, Schimper (Font., Mon. vi, p. 11).
Asterocarpus Virginiensis, Font. (do., p. 45).
Pecopteris rarinervis, Font. (do., p. 49).
Cladophlebis subfalcata, Font. (do., p. 49).
Lonchopteris Virginiensis, Font. (do., p. 51).

Towards the bottom, at Carbon Hill, Va.:

Schizoneura planicostata, Rog. (Font., Mon. vi, p. 16).
Acrostichides rhombifolius, Font. (do., p. 32).
Mertensides bullatus, Bunb. (do., p. 39).
Asterocarpus Virginiensis, Font. (do., p. 45).
Pecopteris rarinervis, Font. (do., p. 49).
Cladophlebis auriculata, Font. (do., p. 50).
Pseudodanæopsis reticulata, Font. (do., p. 60).
Ctenophyllum Braunianum, var. *a*, Goepp. (do., p. 73).
Podozamites tenuistriatus, Rog. (do., p. 79).
Baiera multifida, Font. (do., p. 88).

Towards the bottom, at Deep Run, Va.:

Podozamites tenuistriatus, Rog. (Font., Mon. vi, p. 79).

Towards the bottom, in the Richmond basin, Va.;

Catopterus gracilis, J. H. R. (Newb., Mon. xiv, p. 11).
Dictyopyge macrura, Egt. (do., p. 11).
Ischypterus ovatus W. C. R. (do., p. 11).

Towards the bottom, in the Farmville, Cumberland county, Va., area :

Equisetum Rogersi, Schimper (Font., Mon. vi, p. 12).
Pterophyllum decussatum, Emmons (do., p. 67).
Podozamites tenuistriatus, Rog. (do., p. 79).
Cheirolepis Münsteri, Schimper (do., p. 89).
Bambusium (?) (do., p. 90).

ERRATA.

Please insert the two following lists of fossils at the first break on page 209:

Towards the bottom, about two miles north of west of Emigsville, York County, Pa.:

Belodon Priscus, Leidy (Cope, A. P. S. Proc., 1886, Vol. xxiii, p. 403).
Belodon Carolinensis, Emmons (do., p. 403).
Palæosaurus Fraserianus, Cope (do., p. 404).
Suchoprion cyphodon, Cope (do., p. 404).
" aulacodus, Cope (do., p. 404).
Clepsysaurus Veatleianus, Cope (do., p. 404.)
Palæoctonus appalachianus, Cope (do., p. 404).
Thecodontosaurus gibbidens, Cope (do., p. 404).

Towards the bottom, four miles "eastward" from the Goldsboro fossil footprints, York Co., Pa.:

Ramulus rugosus, Wanner (Pa. Geol. Rep., 1887, p. 27).

On page 212, eight lines from the top, instead of "Reading" read *Pennsylvania*.

On page 214, seven lines from the top, instead of "bottom" read *top*.

Towards the bottom, in the Hanover county, Va., area :

Equisetum Rogersi, Schimper (Font., Mon. vi, p. 12)
Macrotaeniopteris magnifolia, Schimper (do., p. 20).
Cladophlebis rotundiloba, Font. (do., p. 53).
Cycadites tenuinervis, Font. (do., p. 84).

Near the bottom, near Durham, Conn.:

Baiera Münsteriana, Ung. (Newb., Mon. xiv, p. 84).
Schizoneura planicostata, Rogers (do., p. 87).
Pachyphyllum brevifolium, Newb. (Newb., Mon xiv, p. 89).
Otozamites latior, Saporta (do., p. 90).
" brevifolius, T. Br. (do., p. 91).
Cycadiocarpus Chapini, Newb. (do., p. 92).
Loperia simplex, Newb. (do., p. 93).
Clathropteris platyphylla, Brong. (do., p. 94).
Ischypterus micropterus, Newb. (do., p. 32).
Ischypterus tenuiceps, Ag. (do., p. 34).
" minutus, Newb. (do., p. 48).
Catopterus Redfieldi, Egerton (do., p. 53).
" gracilis, J. H. R. (do., p. 55).
" minor, Newb. (do., p. 57).
" ornatus, Newb. (do., Pl. xviii).
" anguilliformis, W. C. R. (do., p. 60).
Ptycholepis Marshii, Newb. (do., p. 67).
Diplurus longicaudatus, Newb. (do., p. 74).

Near the bottom, at Middlefield, Conn.:

Ischypterus ovatus, W. C. R. (Newb., Mon. xiv, p. 27).
Ischypterus fultus, Ag. (do., p. 34).
Brontozoum giganteum, E. H. (Suppl. Ichn., p. 24).
Plesiornis æqualipes, E. H. (Ichn., p. 105).
Typopus gracilis, E. H. (do., p. 106).

Near the bottom, at Middletown (west of the village), Conn.:

Fucoid, undetermined (Hitchc., 1841, p. 453).
Catopterus gracilis, J. H. R. (Newb., Mon. xiv, p. 35).
Catopterus anguilliformis, W. C. R. (?) (do., p. 59).
Anisopus Deweyanus, E. H. (Ich., p. 61).
" gracilis, E. H. (do., p. 62).
Chimaera Barratti, E. H. (?) (do , p. 119).
Cunicularius retrahens, E. H. (do., p. 163).

Near the bottom, at Westfield, Conn.:

Ischypterus ovatus, W. C. R. (Newb., Mon. xiv, p. 27).
Ischypterus fultus, Ag. (do., p. 34).
Ischypterus parvus. W. C. R. (?) (do., p. 45).
Catopterus anguilliformis, W. C. R. (?) (do., p. 59).

Near the bottom, at the Cove, in Wethersfield, Conn.:

Fucoid, undetermined (see Hitchcock, Mass. Geol. Rep., 1841, p. 450).
Plants, undetermined (do., p. 451).
Coprolites (?) (do., p. 461).
Brontozoum giganteum, E. H. (Suppl., p. 24).
Brontozoum minusculum, E. H. (do., p. 24).
Brontozoum divaricatum, E. H. (C. H. H., Bost. Nat. Hist. Soc., xxiv, p. 121).
Brontozoum Sillimanium, E. H. (do., p. 121).
Argozoum disparidigitatum, E. H. (Ich., p. 82).
Argozoum paridigitatum, E. H. (do., p. 82).
Grallator cuneatus (C. H. H., Bost. N. H. S., xxiv, p. 121).
Grallator tenuis (do., p. 121).
Corvipes lacertoideus, E. H. (do., p. 122).
Anomoepus curvatus (do., p. 121).
Platypterna Deaniana, E. H. (Ich., p. 83).
" tenuis, E. H. (do., p. 84).
" delicatula, E. H. (do., p. 84).
Ornithopus gallinaceus, E. H. (do., p. 87).
" gracilior, E. H. (do., p. 88).
Tridentipes insignis, E. H. (do., p. 91).
Plectropterna minitans (do., p. 109).
" elegans, E. H. (C. H. H., B. N. H. S., xxiv, p. 122).
Plectropterna gracilis, E. H. (do., p. 122).
Pletropterna lineans, E. H. (Suppl., p. 71).
Plesiornis giganteus, C. H. H. (B. N. H. S., xxiv, p. 122).
Plesiornis æqualipes, E. H. (do., p. 122).
" n. sp. (do , p. 122).
Trihamus elegans, E. H. (do., p. 122).

Trihamus magnus, C. H. H. (do., p. 122).
Triænopus leptodactylus, E. H. (Ichn., p. 111).
Harpedactylus, n. sp. (C. H. H., B. N. H. S., xxiv, p. 122).
Typopus abnormis, E. H. (do., p. 122).
Comptichnus, n. sp. (do., p. 122).
Ancyropus heteroclitus, E. H. (Ich., p. 139).
Acanthichnus cursorius, E. H. (do, p. 139).
Acanthichnus cursorius var. trilinearis, E. H. (do., p. 139).
Acanthichnus cursorius var. alatus, E. H. (do., p. 139).
Conopsoides larvalis, E. H. (Ich., p. 152).
Unisulcus minutus (C. H. H., B. N. H. S., xxiv, p. 122).
Bisulcus (do., p. 122).
Trisulcus (do., p. 122).
Cochlichnus, 2 sp. (do., p. 122).
Sagittarius and other footmarks (do., p. 122).

Near the bottom, at Mittineaque Falls, in West Springfield, Mass.:

Footmarks (Hitchcock, Mass. Geol. Rep., 1841, p. 466).

Near the bottom, at West Springfield, Mass.:

Coprolite (?) (Hitchcock, Mass. Geol. Rep., 1841, p. 461).

Near the bottom, in southeastern Northampton, Mass.:

Anisopus gracilis, E. H. (Ich., p. 62).
Brontozoum minusculum, E. H. (do, p. 66).
Brontozoum exsertum, E. H. (do, p. 67).
" validum, E. H. (do, p. 68).
" Sillimanium, E. H. (do., p. 69).
Brontozoum isodactylum, E. H (do., p. 70).
Brontozoum giganteum, E. H. (Sup., p. 24).
" approximatum, E. H. (do., p. 24).
Tridentipes ingens, E. H. (Ich, p. 89).
" insignis, E. H. (do., p. 91).
Palamopus Clarki, E. H. (do., p. 127).

Near the bottom, in South Hadley, Mass.:

Anisopus gracilis, E. H. (Ich., p. 62).
Brontozoum Sillimanium, E. H. (do., p. 69).
" isodactylum, E. H. (do., p. 70).
Grallator cursorius, E. H. (do., p. 73).
Grallator tenuis, E. H. (do., p. 73).
" gracillimus, E. H. (do, p. 74).
Batrachoides nidificans, E. H. (do., p. 123).

Near the bottom, in the north part of South Hadley, Mass.:

Anisopus Deweyanus, E. H. (Sup., p. 45).
Brontozoum giganteum, E. H. (Sup., p. 24).
Grallator cuneatus, E. H. (Ich., p. 75).
Batrachoides nidificans (do, p. 123).
Otozoum Moodii, E. H. (do., p. 125).

Near the bottom, at Whitmore's Ferry, in Sunderland, Mass.:

Plants (Hitchc., Mass. Geol. Rep., 1841, p. 450).
Fishes (do., p. 458).
Schizoneura planicostata, Rog. (Newb., Mon. xiv, p. 12).
Clathropteris platyphylla, Brong. (do., p. 94).
Pachyphyllum simile, Newb. (do., p. xxii).
Ischypterus ovatus, W. C. R. (do, p. 27).
" Marshii, W. C. R. (do., p. 29).
" Agassizii, W. C. R. (do., p. 30).
" parvus, W. C. R. (do, p. 45).
" latus, J. H. R. (do, p. 46).
" tenuiceps, Ag. (do., Pl. v, vii).

Near the bottom, at Marsh's quarry, in the southwest part of Montague, Mass.:

Anticheiropus pilulatus, E. H. (Sup., p. 10).
Tridentipes elegans, E. H. (do., p. 90).
Tridentipes insignis, E. H. (do., p. 91).
Chimæra Baratti, E. H. (?) (do., p. 119).

Near the bottom, at two miles south of Turner's Falls, in Montague, Mass.:

Tridentipes elegans, E. H. (Ich., p. 90).

Near the bottom, in Montague, Mass:

Clathropteris, obscure (Font., Mon. vi, p. 58).

Near the bottom, in the north part of Montague, Mass.:

Tridentipes elegans, E. H. (Ich., p. 90).

Near the bottom, at the Horse Race, in Gill, Mass.:

Brontozoum giganteum, E. H. (Sup., p. 24).
" approximatum, E. H. (do., p. 24).
Argozoum paridigitatum, E. H. (Ich., p. 82).
Ornithopus gallinaceus, E H. (do., p. 87).
Tridentipes ingens, E. H. (do., p. 89).
" elegans, E. H. (do., p. 90).
" insignis, E. H. (do., p. 91).
Hoplichnus equus (do., p. 35).

Near the bottom, in Gill, Mass.:

Dictyophyllum, or Camptopteris (Font., Mon. vi, p. 58).

Somewhere near the bottom, at Springfield, Mass.:

Anchisaurus polyzelus (Hitchcock, Supp. Ichn., 1865, p. 39; and Marsh, Am. Jour. Sci, xxxvii, p. 332, 1889).
Coprolite (?) (Hitchc., Mass. Geol. Rep., 1841, p. 461).

Somewhere near the bottom, one mile south of Chicopee, on the road to Springfield, Mass.:

Ancyropus (Sauroidichnites) heteroclitus, E. H. (1841, p. 479).
Plectropterna (Sauroidichnites) minitans, E. H. (1841, p. 482).
Polemarchus gigas, E. H. (Ich., p. 108).

Somewhere near the bottom, at Chicopee, Mass.:

Plant resembling Lemania (Hitchc., Rep., 1841, p. 450).

Somewhere near the bottom, at South Hadley Falls, Mass.:

Plant, undetermined (Hitchc., Mass. Rep., 1841, p. 452).
Harpagopus dubius, E. H. (?) (Ich., p. 148).
Fishes (Newb., Mon. xiv, p. 21).

Towards the bottom, at Chicopee Falls, Mass.:

Plant, perhaps a Fucoid (Hitchc., Mass. Rep., 1841, p. 453).
Footmarks (do., p. 466).
Pycnodont fish tooth (do., p. 460).
Acentrophorus Chicopensis, Newb. (Newb., Mon. xiv, p. 70).
Argozoum Redfieldianum, E. H. (Ich., p. 82).
Argozoum disparidigitatum, E. H. (Ich., p. 82).
Ornithopus gallinaceus, E. H. (do., p. 87).
Polemarchus gigas, E. H. (do, p. 108).

Towards the bottom, at Ellingtons, N. C.:

Laccopteris Münsteri, Schenk (Font., Mon. vi, p. 102).
Laccopteris elegans, Presl. (do., p. 102).
Lonchopteris oblongus, Emmons (do., p. 103).
Sagenopteris rhoifolia (do., p, 104).
Acrostichides rhombifolius, Font. (do., p. 105).
Palissya diffusa, Emmons (do., p. 107).
Cheirolepis Münsteri, Schimper (do., p. 108).
Equisetum Rogersi, Schimper (do., p. 109).
Podozamites Emmonsi, Font. (do., p. 111).
Pterophyllum decussatum, Emmons (do., p 111).
Pseudodanæopsis reticulata, Font. (do., p. 116).
Ctenophyllum, type of imbricatum (do., p. 116).

Below the middle, at Klinesville, N. J.:

Lamellibranch, undetermined (N. J. Geol. Rep., 1888, p. 29).
Cypris (do., p. 30).
Estheria (do., p. 30).

Near the middle, at Manchester, Conn.:

Anchisaurus major, Marsh (Am. Jour. Sci., 1889, xxxvii, p. 331).

About the middle, at Haywood, N. C.:

Cladophlebis obtusiloba, Andrae (?) (Font., Mon. vi, p. 105).
Ctenophyllum Braunianum, var. β, Goepp. (do., p. 112).

Perhaps about the middle, at five miles north of Haywood, N. C.:

Baiera multifida, Font. (Font., Mon. vi, p. 118).

Perhaps about the middle, at House's quarry, on the Haw river, N. C.:

Ctenophyllum Emmonsi, Font. (Font., Mon. vi, p. 113).
Ctenophyllum lineare, Font. (do., p. 114).
Pterophyllum spatulatum, Font. (do., p. 114).
Zamiostrobus Emmonsi, Font. (?) (do, p. 117).

At about 1500 feet below the top, at the south entrance of the Reading railroad tunnel, near Phœnixville, Pa.:

Plants (H. C. Lewis, Science, 1884, Vol. iii, p. 295).
Unio, 2 species (do., p. 295).
Marine lamellibranchs, 3 species (do., p. 295).
Ganoid fish (do., p. 295).
Saurian (?) (do., p. 295).

At about 1000 feet below the top, in the Reading railroad tunnel, near Phœnixville, Pa.:

Estheria Hindei, T. Rup. Jones (Geol. Mag., 1891, viii, p. 51).
Estheria Lewisii, T. Rup. Jones, "Red S. S. of Bucks county, Pa." (do., 1890, vii, p. 385).
Ganoid fishes (Leidy, A. N. S. Proc., 1859, Apr. 5).
Clepsysaurus (?) teeth (do., do.). (These are Belodon teeth, according to Cope.)
Eurydorus serridens (do., do.).
Compsosaurus (?) (do., do.).
Eupelor durus (Cope, do, 1866, p. 249, and A. P. S. Trans., 1868, xiv, p. 25).
Belodon Carolinensis, Emm. (Cope, A. P. S. Proc., 1886, xxiii, p. 403).
Belodon lepturus, Cope (A. P. S. Trans., 1868, xiv, p. 59).
Rhabdopelix longispinis, Cope (?) (do., p. 174).
Dicynodon rosmarinus (do., 232).
Batrachian tracks (Cope, do., p. 242).
Coprolites (Wheatley, A. N. S. Proc, 1859, p. 110).
Limulus (?) (do., p. 110).
Equisetum columnare, Brg. (do., p. 110).
Pterozamites longifolius, Emm. (do., p. 110).
Gymnocaulus alternatus, Emm. (do., p. 110).
Fir Cones (Lea, A. J. S., 1856, xxii, p. 123).
Calamites punctata (do., p. 123).
Dictyocaulus striatus (do., p. 123).
Estheria ovata, Lea (Wheatley, A. N. S. Proc., 1861, Vol xxxii, p. 43).
Estheria parva, Lea (do., p. 43).
Cypris, 2 species (do, p. 43).
Myacites Pennsylvanicus, Conrad (A. N. S. Proc., 1857, p. 86).
Radiolepis speciosus, Emm. (Lea, do, 1857, July 7).
Centemodon sulcatus, Lea (do., 1856, Mar., p. 77).
Chelichnus Wymanianus, Lea (do., p. 77).
Catopterus gracilis, Redf. (Wheatley, A. J. S., 1861, p. 41).

At about 1000 feet below the top, near Yerkes Station, Montgomery county, Pa.:

Radiolepis elegans Emm. (Leidy, A. N. S. Proc., 1876, May 9, p. 81).

At about 1000 feet below the top, at the Gwynedd tunnel, Montgomery county, Pa.:

Cypris (Leidy, Ac. Nat. Sci. Proc., 1857, June 16).
Batrachian (?) bones and teeth (do., do.).
Radiolepis speciosus, Emm. (Lea, do., 1857, July 7).
Eurydorus serridens (?) (Leidy, do., 1859, Apr. 5).
Rhabdopelix longispinis, Cope (A. P. S. Trans., 1868, xiv, p. 174).
Turseodus acutus, Leidy (A. N. S. Proc., 1857, June, p. 167).

Towards the top, "2000 feet or more above the coal measures," at Lockville, Chatham county, N. C.:

Sagenopteris rhoifolia (Font., Mon. xiv, p. 104).
Palissya Braunii, Endl. (do., p. 107).
Cheirolepis Münsteri, Schimper (do., p. 108).
Cycadites Roemeri, Schenk (?) (do., p. 109).
Cycadites longifolius, Emm. (?) (do., p. 110).
Pterophyllum pectinatum, Emm. (do., p. 112).
Zamiostrobus Emmonsi, Font. (?) (do., p. 117).
Otozamites Carolinensis, Font. (do , p. 117).
Araucaria (?) (do., p. 118).
Araucarites Carolinensis, Font. (do.. p. 119).

Towards the top, at Ketch's mills, in the east part of East Windsor, Conn.:

Bones, undetermined (Hitchc., Mass. Geol. Rep., 1841, p. 503).

Towards the top, at Ellington (Ct.):

Bones, undetermined (Hitchc., Mass. Geol. Rep., 1841, p. 504).

Perhaps towards the top, at Amherst, Mass.:

Fishes (Newb., Mon. xiv, p. 21).

Towards the top, at Washington's Crossing, N. J.:

Estheria (N. J. Geol. Rep., 1888, p. 30).
Fishes (do., p. 30).

Very near the top, at Tumble Station, N. J.:

Footmarks (Nason, N. J. Geol. Rep., 1888, p. 29).

Lansdale Shales.

Towards the bottom, at Little Falls and Pleasantdale, N. J.:

Plants, abundant (Nason, N. J. Geol. Rep., 1888, p. 23).

Towards the bottom, near Feltville, N. J.:

Cypris (?) (Nason, N. J. Geol. Rep., 1888, p. 22).

Towards the bottom, at Fields' copper mine, near Warrenville, and near Plainfield, N. J.:

Estheria (Nason, N. J. Geol. Rep., 1888, p. 30).
Fishes (do., pp. 29, 30).

Towards the bottom, near Washingtonville, N. J.:

Plants (Nason, N. J. Geol. Rep., 1888, p. 27).

Towards the bottom, near Martinsville, N. J.:

Tree trunks and ferns (Nason, N. J. Geol. Rep., 1888, p. 27).

Towards the bottom, near Pluckamin, N. J.:

Plants (Nason, N. J. Geol. Rep., 1888, p. 23).

About the middle, near New Providence, N. J.:

Plants (Nason, N. J. Geol. Rep., 1888, p. 28).

About the middle, near Whitehall, N. J.:

Tridentipes ingens, E. H. (C. H. H., Bost. Soc. N. Hist., xxiv, p. 122).
Brontozoum giganteum, C. H. H. (do., p. 122).
Brontozoum minusculum, E. H. (do., p. 122).
Brontozoum Sillimanium, E. H. (do., p. 122).
Grallator formosus, E. H. (do., p. 122).
Grallator parallelus, E. H. (do., p. 122).
" cursorius, E. H. (do., p. 122).
Anomœpus intermedius, E. H. (do., p. 122).

Apatichnus crassus, C. H. H. (do., p. 122).
Anisichnus gracilis, E. H. (do., p. 122).
Brontozoum isodactylum (Cook, N. J. Geol. Rep., 1885, p. 96).
Brontozoum divaricatum, E. H. (do., p. 96).

Towards the top, at Pompton furnace, N. J.:

Ischypterus Agassizii, W. C. R. (Newb., Mon. xiv, p. 30).

Perhaps towards the bottom, one mile south of Goldsboro, York county, Pa.:

Ramulus rugosus, Wanner (A. Wanner, Pa. Geol. Rep., 1887, p. 27).
Algæ (do., p. 21.)
Anomœpus gracillimus, C. H. H. (Bost. Nat Hist. Proc., xxiv, p. 123).
Brontozoum Sillimanium, E. H. (do., p. 123).
Anisichnus gracilis, E. H. (do., p. 123).

Perkasie Shales.

Near the bottom, at Smith Clark's quarry, near Milford, N. J.:

Palæophycus limaciformis, H. C. Lewis (A. N. S. Proc., Nov., 1880, p. 93).
Schizoneura planicostata, Rog. (Newb., Mon. xiv, p. 11).
Equisetum Rogersi, Schimper (do., p. 85).
Cheirolepis Münsteri, Schimper (do., p. 89).
Clathropteris platyphylla, Brg. (do., p. 94).
Grallator parallelus, E. H. (C. H. H., Bost. Nat. Hist. Soc., xxiv, p. 122).
Grallator cuneatus, Barratt (do., p. 122).
" gracilis, C. H. H. (do., 122).
Chimærichnus ingens, C. H. H. (do., p. 122).
Polemarchus gigas, E. H. (do., p. 122).
Argozoum disparidigitatum, E. H. (do., p. 122).
Otozoum parvum, C. H. H. (do., p. 122).
Unisulcus magnus, C. H. H. (do., p. 122).
Sagittarius (do., p. 122).
Brontozoum isodactylum, E. H. (Eyerman, Ac. Nat. Sci. Proc., 1889, p. 32).
Grallator tenuis, E. H. (do., p. 32).
Anomœpus minor, E. H. (do., p. 32).
Harpagopus dubius, E. H. (do., p. 32).
Unisulcus marshi, E. H. (do., p. 32).
" minutus, E. H. (do., p. 32).

Near the bottom, at Boonton, N. J.:

Ischypterus ovatus, W. C. R. (Newb., Mon. xiv, p. 27).
Ischypterus Agassizii, W. C. R. (do., p. 30).
" tenuiceps, Ag. (do., p. 34).
" fultus, Ag. (do., p. 34).
" robustus, Newb. (do., p. 37).
" elegans, Newb. (do., p. 37).
" alatus, Newb (do., p. 38).
" modestus, Newb. (do., p. 39).
" lenticularis, Newb. (do., p. 39).
" lineatus, Newb. (do., p. 41).
Ischypterus macropterus, W. C. R. (do., Pl. xii).
Ischypterus parvus, W. C. R. (?) (do., p. 45).
Ischypterus gigas, Newb. (do., Pl. xiv).
Catopterus parvulus, W. C. R. (do., p 61).
" gracilis, J. H. R. (do., p. 55).
Diplurus longicaudatus, Newb. (do., p. 74).
Brontozoum approximatum, C. H. H. (Bost. Nat. Hist. Soc., xxiv, p. 123).
Grallator formosus, E. H. (do., p. 123).

Towards the bottom, at New Vernon, N. J.:

Footmarks, imperfect (Cook, N. J. Geol. Rep., 1885, p. 95).

Norristown Shales.

About 5000 feet above the bottom, in Upper Milford township, Lehigh county, Pa.:

Clepsysaurus Pennsylvanicus, Lea (Lea, A. N. S. Jour., 1883, p. 185).

These lists probably show satisfactorily that there is no serious paleontological obstacle to accepting the views here set forth in regard to the New Red; certainly none to compare in seriousness with the obstacles that were boldly overridden repeatedly in making the Portland and Newark fossils Triassic.

Although the account just given puts quite another face upon the New Red with the unquestionably great thickness in Pennsylvania, and the partly conjectural, but quite harmoniously corresponding, condition of the beds in other States, yet it is clear that what is most extraordinary about the present views, so far as they are speculative, is that, for New Red speculations, they are so little extraordinary, so free from extravagance, so natural, probable and simple, yet so fully capable of explaining all the observed facts. It is seen that, although the New Red beds do not everywhere exist in the same completeness as in Montgomery county, yet that certain portions are pretty fully represented in distant States, the lower third in Connecticut, the lower half in Northeastern New Jersey, and the lower portions and upper portions in separate basins in Virginia. It is further plain that almost all, if not quite all, the fossils from which the Rhaetic, or Triassic, or Jurassic age of our New Red has been inferred, come from the Gwynedd shales alone; and that the few fossils from other parts of the whole New Red series have either been useless as indications of age. or have been flatly disregarded. Hence it is not improbable that the Norristown shales, with the great calamite near Doylestown, the apparent Lepidodendron at Newark and Belleville, and the Palæophycus at Portland, may after all prove to be at least as old as the Permian. It seems, indeed, highly probable that the well-ascertained great thickness of 27,000 feet in Montgomery county should represent more than one limited paleontological period, and not only that it should include the Permian, but that the very extensive upper third of that space, hitherto almost devoid of reported fossils, should turn out to be much newer than the Triassic. Those upper beds have also shown here and there imperfect fossil traces, and as there are occasional beds of green shales among the predominant red ones, there is reason to hope that more abundant and perfect fossils may some day be found.

As for the trap, it seems impossible to doubt any longer that all the conformable trap sheets are overflows contemporaneous with the sedimentary beds, and not subsequent intrusions.

It is furthermore at any rate evident that thoroughly geological methods, as distinguished from purely paleontological ones, are of great importance in working out the geology, that is, the structure, the cross-sections, the columnar section and the outcrops of any region, but especially of one where fossils are scarce; and that the topography is extremely useful as an aid to understanding the geology.

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Remarks on Mr. Lyman's Paper.

By Dr. Persifor Frazer.

The paper of Mr. Lyman is astonishing in the fact that it does not mention the seven years' work by the Second Geological Survey of Pennsylvania on the New Red in York, Adams, Cumberland and Lancaster counties; although the method he advocates was the very method there adopted, viz., the careful topographical and geographical plotting of the region and the accurate location of every dip. There is neither justice nor expediency in ignoring years of work by a colleague, especially when one occupies a quasi directorship of the Survey under whose auspices the work was done.

From the section across the counties of York and Adams, from the town of York to Dillsburg, made in 1875, careful descriptions of the successive beds were made, as well as notes of their dip, and from these data a column was constructed for correlation with the columns of the Permian, Triassic and Jurassic in England and in Germany. In a paper contributed to Vol. v, *Trans. American Institute of Mining Engineers*, founded on the work done in 1874 in Southeast Pennsylvania, it was suggested that the basal conglomerate of the New Red might find its analogue in the magnesian limestone of England and the Zechstein of Germany, both of which represent the top of the Permian in the respective countries.

The thickness of the strata calculated by H. D. Rogers from 'the Yardleyville-New Hope-Attleboro' section, and confirmed by the writer, was 51,500 feet, or 15.75 kilometers, but neither Prof. Rogers nor the speaker believed that this represented the actual state of the case. It was stated that the New Red seemed to extend from some point in the Permian, at least, to the base of the Lias, including all the rocks attributed to the Trias and the beds below it, except the lower Rothliegendes of the German scale.

It is added, in the same paper, as a matter of frequent remark that all the beds of the "New Red" are not red. On the contrary, perhaps one-half of the whole series presents to the eye a lead-gray and drab color. It was suggested as possible that the black calcareous slates of Phœnixville might represent a lower horizon than the coal-bearing belt (near Ewingsville?) referred to in the catalogue of specimens of Report C, of York county, for 1874.

With reference to the subordinate position which paleontological should bear to stratigraphical evidence, the case would seem to be not quite fairly stated. If there were everywhere a complete column of strata of which the mutual relations were unmistakable, then paleontological evidence would be forced to conform itself to the column as best it might. But the case is like that of the relation between the astronomical transit and the compass, or the level and the barometer—the latter is invaluable

where the former cannot be employed. For coördination of series in two distant places between which there is no stratigraphical connection, paleontological evidence is the only evidence available.

On the Lungs of the Ophidia.

By Prof. E. D. Cope.

(*Read before the American Philosophical Society, May 18, 1894.*)

The condition of knowledge as to the characters of the lungs of snakes was stated by Stannius, in 1856,* as follows: "The detailed accounts as to the single or double character of the lungs leave much to be desired. Among Ophidia Angiostomata there possess a single sack, Rhinophis and all Typhlopidæ which have been examined; as to the Tortricidæ [Ilysiidæ], there are apparently species with two lungs (*T. xenopeltis*) [= *Xenopeltis unicolor*], and others with a single lung (*T. scytale*) [= *Ilysia scytale*]. Among Eurystomata, all the Peropoda (Boa, Python, Eryx) possess apparently two lungs. The Calamarina that have been investigated have one lung. Among Colubrina and Glyphodonta, there are great variations. All the Coronellæ of Schlegel possess, according to Schlegel, a single lung. I find the lung single in *Rhachiodon scaber* [*Dasypeltis*]. *Tropidonotus natrix* [*Natrix vulgaris*] has a very small rudiment of a second lung. *Coluber* [*Spilotes*] *variabilis* possesses, according to Schlegel, the rudiment of a second lung. According to the statement of Meckel, this rudiment is common in Coluber. The Xenodons have, according to Schlegel, a single lung (*X. severus* and *X. rhabdocephalus*). In Heterodon I find a rudimental second lung. The Lycodons, according to Schlegel, possess a single lung; as also do Psammophis and Homalopsis. In *Dendrophis colubrina* Schlegel found the rudiment of the second lung. In Dipsas, according to Schlegel, there are variations; but he states that *D. multimaculata*, *D. lævis* and *D. annulata* [*Sibon annulatum*], have but one lung. The Achrochordina have but one lung. Among Hydrophidæ I found in three species of Hydrophis the lung-sack simple. Meckel states that Platurus has a very small rudiment of a second lung. Among the remaining poisonous snakes there is an insignificant rudiment of the second lung in the Elapina and Crotalina; while the Viperina possess an entirely simple lung."

The absence of tangible external characters which furnish indications of affinity in the Ophidia is well known. The important characters to be found in the skeleton were mostly pointed out by Müller, and Duméril and Bibron examined and utilized the characters of the dentition. The

* *Zootomie der Amphibien*, p. 108.

characters derived from the skeleton define only the larger divisions; while those derived from the teeth are not sufficiently numerous and important, with some exceptions, to indicate all of the affinities of the genera. I think I have added materially to the means at our disposal for classifying the Ophidia, by a study of the hemipenis.* The criteria will however not be sufficient until the entire anatomy is worked out, and in the present paper I add what may be found by a study of the lungs. It seemed probable to me that an organ which presents so much variation, as above stated by Stannius, must furnish some important clues. My examinations embraced about one hundred and fifty species, which represent nearly all the leading types. The results are presented in the following pages. It will be seen that they correct the statements of Schlegel and Stannius in a number of important respects.

The snakes with rudimental posterior limbs (Peropoda), show in the character of their lungs, what they show in the rudimental limbs themselves, and in the hemipenis, the nearest relationships to the Lacertilia. They possess, with an exception to be noted later, two well-developed lungs, one of which is larger than the other. The smaller lung lies to the right side and ventrally, while the larger one lies to the left side and dorsally. In some species the dorsal and ventral relation is more pronounced than in others. In the Colubroidea the right or ventral lung is generally present, but of very much reduced proportions, the usual size being from two to five millimeters in length. It is connected with the other lung by a foramen which perforates the tracheal cartilage at a point a little beyond the apex of the heart, and opposite to the proximal part of the dorsal lung. It is sometimes connected to the dorsal lung by a short tube, in which cartilaginous half rings are seen in but two of the genera examined, viz., Heterodon and Conophis. The lumen of the rudimental lung may be lined by the same reticulate structure as is seen in the dorsal lung, or its walls may be smooth. In some Colubroidea the rudimental lung is absent, but such species are relatively few.

The dorsal lung may present proximally alongside of the trachea an auricle or pocket, and this is so developed in the genus Heterodon as to reach to the head, without communication with the trachea, other than that furnished by the normal portion of the lung. In the Solenoglypha, without exception, this extension of the dorsal lung is present, and extends to the head, and its lumen is continuous with the trachea throughout its length. The same structure exists in the genera Hydrus and Hydrophis; and also in the peropodous genus Ungualia, which differs besides from other Peropoda in having but one posttracheal lung. Finally the tracheal lung, as I shall call it, is distinct from the true lung in Platurus and in Chersydrus. In the former of these genera the trachea is not separate from the lumen; while in Chersydrus it is distinct. It, however, communicates with the cells of which the lung consists in this genus by a series of regularly placed foramina on each side. There is no lumen in the tracheal lung in

* *American Naturalist*, 1893, p. 477.

Chersydrus. In Typhlops we have a still further modification of the tracheal lung. It is without lumen, and is composed of coarse cells of different sizes. These have no communication with the trachea or lung that I can discover, nor any efferent orifice. It has occurred to me that this structure, which extends from the heart to the throat, may not be a pulmonary organ.

I have referred to the dorsal and ventral positions of the two lungs. The rudimental lung is to the right of the dorsal lung in the Colubroidea, but in the Ilysiidæ it is to the left. It is quite questionable which lung this rudiment in this family really represents. In the Typhlopidæ, the single lung is on the right side and extends from the heart to the liver. It has the position of the rudimental lung of the Colubroidea, and may represent it. I cannot decide this question without further material. In Glauconia there is but one true lung, and this is ventral in position, and originates to the right of the heart, so that in this genus also it may represent the rudimental lung of the Colubroidea. There is here no tracheal lung or organ.*

I now give a synopsis of the characters observed in the species examined.

CATODONTA.

Glauconia dulcis B. and G. A single elongate right lung; no rudiment of left lung. No tracheal lung.

EPANODONTA.

Typhlops liberiensis Hallow.; *T. reticulatus* L. A right lung which is not elongate; no rudimental left lung. A cellular body surrounding the trachea, and extending from the heart to the throat, without lumen or connection with the trachea or lung.

The presence of the tracheal lung (?) and the freedom of the maxillary bone are points of resemblance to the Solenoglypha!

TORTRICINA.

Ilysiidæ.

Two lungs, the ventral one to the left side of the middle line, rudimental, but lined with pulmonary tissue like the other lung, and less reduced than in the Colubroidea.

Cylindrophis maculata L. The right lung extends only to the liver.

Ilysia scytale L. The right lung is larger.

Rhinophidæ.

Rhinophis oxyrhynchus Schn. One large left lung and very small (3 mm.) right lung; no tracheal lung. Contrary to the statement of Stannius above quoted, as in Colubroidea generally.

*Cf. Peters, *Reise nach Mozambique*, iii, p. 100, Pl. xivA, 1882.

ASINEA.

PEROPODA.

I. Two well-developed lungs of unequal size; no tracheal lung.

Pythonidæ.

Python regius Shaw; *P. molurus* Linn.; *P. spilotes* Lacep.; *Loxocemus bicolor* Cope.

Boidæ.

Xiphosoma caninum L.; *Epicrates cenchria* L.; *Chilabothrus inornatus* Rein.; *Boa constrictor* L.; *Eunectes murinus* L.; *Eryx johnii* Russ.

Charinidæ.

Besides the absence of coronoid and supra and postorbital bones, this family differs from the Boidæ in the fusion of the nasal bones into a single plate. *Charina bottæ* Blv.

II. One lung without rudiment of a second; a tracheal lung extending from true lung, with which it is continuous, to throat.

Ungaliidæ.

Ungalia maculata Bibr.; *U. melanura* Gray.

COLUBROIDEA.

I. Two well-developed but unequal functional lungs.

Xenopeltidæ.

Xenopeltis unicolor, Reinwt.

II. One functional lung only; the right rudimental lung sometimes possibly with limited function.

Colubridæ.

Lycodontinæ.

Lycodon aulicus L.; *Boaodon infernalis* Gthr.; *Uriechis microlepidotus* Pet.; *Stenorhina ventralis* D. and B.

Colubrinæ.

Elopops modestus Gthr.*; *Coronella girundica* Daud.; *Dianodon semicarinatus* Cope; *Ficimia olivacea* Gray; *Salvadora bairdii* Jan.; *Pityophis sayi* Hobr.; *Epiglottophis pleurostictus* D. and B.; *Spilotes corais* Cuv.; *S. pullatus* L.; *Coluber quadrilineatus* Pallas; *C. obsoletus* Say; *C. quadrivittatus* Holbr.; *Bascanium constrictor* L.; *B. flagellum* Cates-by; *B. mentovarium* D. and B.; *Zamenis atrovirens* Shaw; *Z. korros* L.;

* Position uncertain; perhaps a Lycodontine.

Cyclophis æstivus L. ; *Drymobius pantherinus* Merr. ; *D. boddærtii* Seetz. ; *D. margaritiferus* Schl. ; *Crossanthera melanotropis* Cope ; *Herpetodryas carinatus* L.; *Leptophis præstans* Cope ; *L. mexicanus* D. and B. ; *L. smaragdinus* Boie. ; *Dendrophis picta* L. ; *Dasypeltis palmarum* Leach.

Dipsadinæ.

Dipsas blandingii Hallow. ; *Himantodes gemmistratus* Cope ; *Rhinobothyrum lentiginosum* Scop. ; *Trimorphodon biscutatus* D. and B. ; *Sibon septentrionale* Kenn. ; *Malpolon lacertinum* Wagl. ; *Cladophis kirtlandii* Hall ; *Dryophis fulgida* Daud. ; *Passerita mycterizans* L.

Chrysopeleinæ.

Chrysopelea ornata Shaw.

Xenodontinæ.

Catostoma badium D. and B. ; *Farancia abacura* Holbr. ; *Abastor erythrogrammus* Daud. ; *Opheomorphus fuscus* Cope ; *Helicops angulatus* Linn. ; *H. baliogaster* Cope ; *Dromicus parvifrons* Cope ; *Halsophis leucomelas* D. and B. ; *Xenodon rhabdocephalus* Wied. ; *X. angustirostris* Peters ; *Lystrophis dorbignyi* D. and B. ; *Heterodon nasicus* B. and G. ; *H. platyrhinus* Latr. ; *Hypsirhynchus ferox* Gthr. ; *Uromacer oxyrhynchus* D. and B. ; *U. catesbyi* D. B. Right lung larger in *Uromacer*.

Scytalinæ.

Hydrocalamus quinquevittatus D. and B. ; *Erythrolamprus venustissimus* L. ; *E. fissidens* Gthr. ; *Oxyrrhopus plumbeus* L. ; *O. fitzingerii* Jan. ; *Conophis pulcher* Cope ; *C. sumichrastii* Cope ; *Manolepis nasutus* Cope ; *Jaltris dorsalis* Gthr. ; *Philodryas viridissimus* L. ; *P. olfersii* Licht.

Natricinæ.

Generally a proximal auricle or pocket. *Eutænia proxima* Say ; *E. sirtalis* L., s. s. *sirtalis, obscura* and *parietalis ; Natrix fasciata* L. ; *N. rhombifera* Hallow. ; *N. taxispilota* Holbr.

Appendix to Colubridæ.

In the African *Thrasops flavigularis* Hallow. the right (rudimental) lung measures 5 mm. The trachea is enormously expanded transversely, simulating a tracheal lung, but its inferior wall contains the tracheal cartilages which extend its entire width, and it contains no cells or trabeculæ. An artery with lateral branches extends its entire length, which is from the posttracheal lung to the throat. This character distinguishes this genus from Leptophis.

In the following species I found no trace of the right lung.

Colubrinæ. *Rhinochilus lecontei* B. and G. ; *Cemophora coccinea* Blum. ; *Ophibolus doliatus* L. ; *O. getulus* L. ; *Pityophis melanoleucus* Daud.

Xenodontinæ. *Halsophis angulifer* D. and B. ; *H. vudii* Cope.

Leptognathinæ. I propose this subfamily as distinct from the Xenodontinæ, on account of the presence of a large tracheal lung which is continuous with the normal lung, and with the trachea, and extends to the throat. *Leptognathus nebulatus* L.; *L. garmanii* Cope.

Scytalinæ. *Tachymenis strigatus* Gthr.; *Phalotris lemniscatus* D. and B.; *P. tricolor* D. and B.; *Erythrolamprus bipunctatus* Gthr.

Natricinæ. *Cerberus boæformis; Pseudaspis cana* L.

Acrochordidæ.

Chersydrus granulatus Merr. In this species the heart is at the middle of the length of the body, and the normal lung is posterior to it, extending nearly to the vent. No rudimental lung. A tracheal lung, composed of coarse cells and without lumen, extends from the heart to the head, and is discontinuous with the true lung. The trachea is closed, but communicates with the tracheal lung by a series of symmetrical pores on each sides

Najidæ.

One lung and a rudiment; no tracheal lung. *Pseudechis porphyriacus* Shaw; *Diemenia reticulata* Gray; *Naja tripidians* L.; *Bungarus semifasciatus* Kuhl.

Elapidæ.

No rudimental nor tracheal lung. *Elaps lemniscatus* L.; *E. fulvius* L.; *E. corallinus* L.; *E. multifasciatus* Jan.

Hydrophidæ.

I. One lung and no rudiment, continuous with tracheal lung, which extends to head.

Hydrophis hardwickii Gray (a slight constriction between tracheal and posttracheal lungs); *H. elliotii* Gthr.; *Hydrus bicolor* Daud.

II. A rudimental right lung connected with the left lung, which is separate from the large tracheal lung.

Platurus laticaudatus L.

SOLENOGLYPHA.

A tracheal lung, continuous with the normal lung.

Causidæ.

No rudimental lung.

Causus rhombeatus Licht.

Dendraspididæ.

No rudimental lung.

Dendraspis polylepis Gthr.

Viperidæ.

No rudimental lung.
Clotho arietans L.

Crotalidæ.

I. No rudimental lung.
Bothrops lanceolatus L.; *Ancistrodon piscivorus* Lacep.; *Crotalophorus catenatus* Raf.; *Crotalus adamanteus* Beauv.; *C. confluentus* Say.
II. With a rudimental right lung.
Bothrops pictus Tsch.; *B. erythrurus* Cant.; *Teleuraspis schlegelii* Berth.; *Ancistrodon contortrix* L.; *Crotalus horridus* L.

THE SYSTEMATIC VALUE OF THE PULMONARY CHARACTERS.

I have no doubt of the propriety of the separation of the Ungualiidæ from the other Peropoda, on account of its pulmonary characters. Nor is there any doubt in my mind of the necessity of the separation of the Leptognathinæ from the Xenodontinæ, for similar reasons. The genus Heterodon differs very much from the Xenodontinæ, in the possession of an enormous diverticulum of the lung, but as it is not present in the allied genus Lystrophis Cope, its wider distinction may be a questionable proceeding. The very marked characters of the genus Chersydrus characterize the family, as well as the osteological characters. It remains to be seen whether the family I termed the Nothopsidæ, but which Boulenger unites with the Chersydridæ, agrees with it in pulmonary characters. The remarkable tracheal lung or gland distinguishes the Epanodonta from the Catodonta, emphasizing that observed in the osteology of the skull. The peculiar form and relations of the maxillary bone in this group resemble those of the Solenoglypha, and there may be some possible connection between the groups. The tracheal body may be a degenerate tracheal lung, such as that division possesses.

The value of the rudimental right lung as a character of the Colubroidea is increased by my investigations. In only two genera have I found it present or absent, viz., Halsophis and Pityophis. I am not sure but that I may yet find it in the *P. melanoleucus*, where I have failed hitherto, but I am sure that it is present in some species of Halsophis and wanting in others. A natural group of American Colubrinæ, appears to be characterized by its absence, viz., Rhinochilus, Cemophora and Ophibolus; all genera with an entire anal shield. The development of cartilages in the bronchial foramen or tube of the rudimental lung is not a constant character. I found it in one *Heterodon platyrhinus* and not in another; it is present in *Conophis pulcher*, but absent in *C. sumichrastii*.

The rudimental lung is often concealed from view and difficult to discover. The best test of its presence is the foramen which connects it with

the trachea, which will generally be found piercing the cartilage of the latter near the apex of the heart. The rudimental organ may then be found by inserting a bristle, and observing its destination through the more or less transparent tissues. In but one instance have I found a rudimental lung without a connecting foramen, viz., in the Mexican *Ficimia olivacea*. On the other hand, the foramen may terminate in a small blind sac.

The pulmonary characters may be determined without much dissection. The position of the heart must be first ascertained, and a longitudinal median incision made in the abdominal wall. In all forms except the Epanodonta and Catodonta, the trachea will be found passing to the left side of the heart, and entering the lung near its apex. By splitting the trachea, not too near its abdominal border, on turning the free margin upwards as the snake lies on its back, the *foramen bronchiale* will be seen and its lumen can be explored. The trachea is concealed by the œsophagus, which must be drawn to the left side of the body in order to make the examination. The examination of the tracheal lung requires the division of the abdominal wall further towards the head.

EXPLANATION OF PLATES.

The figures variously reduced; the heart and liver are turned over to show the trachea and lungs.

PLATE XI.

Typhlops liberiensis Hallow.

PLATE XII.

Charina bottæ Blv.

PLATE XIII.

Chersydrus granulatus Merr.

PLATE XIV.

Coluber quadrivittatus Holbr.

PLATE XV.

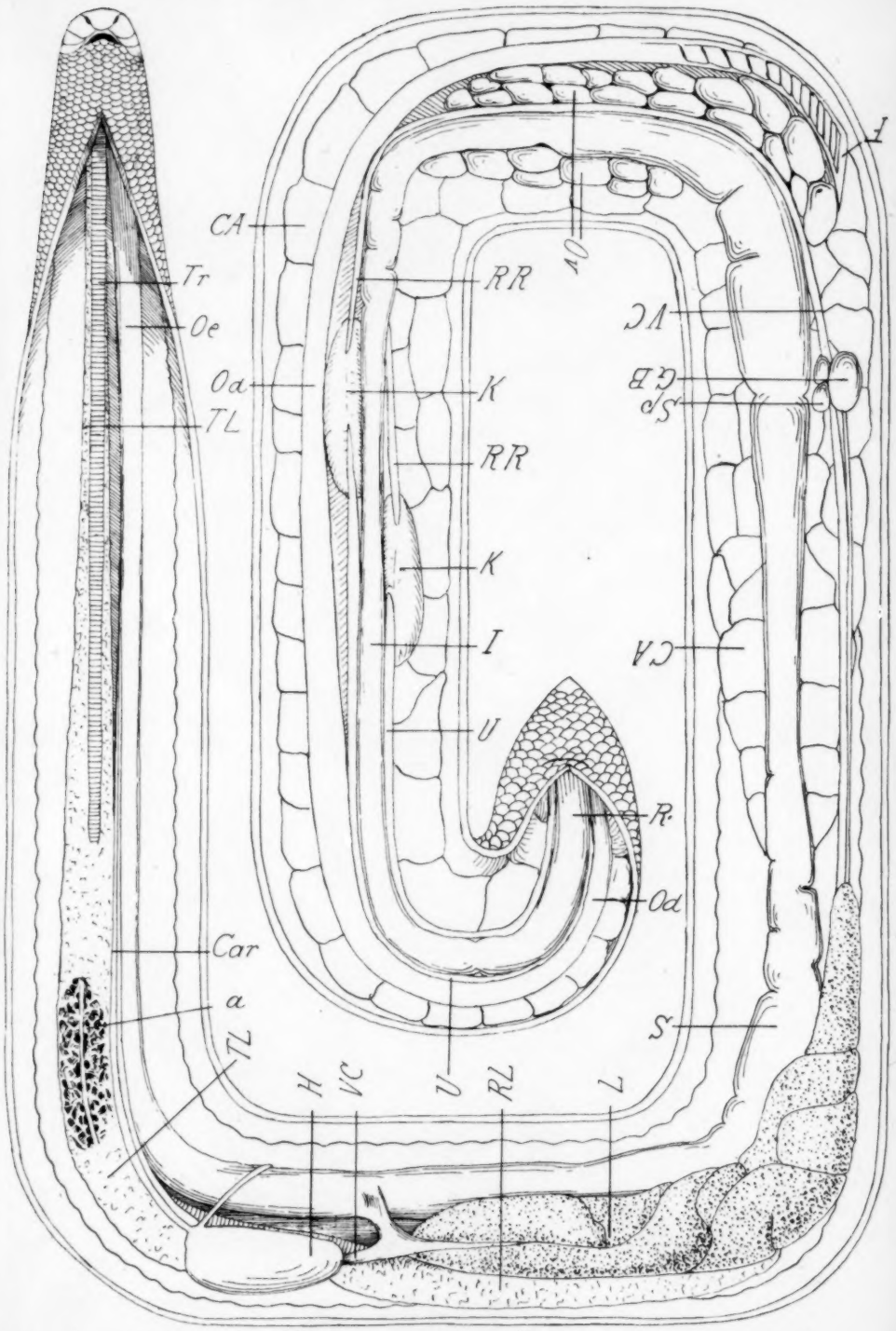
Heterodon platyrhinus Latr.

PLATE XVI.

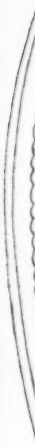
Crotalus confluentus Say.

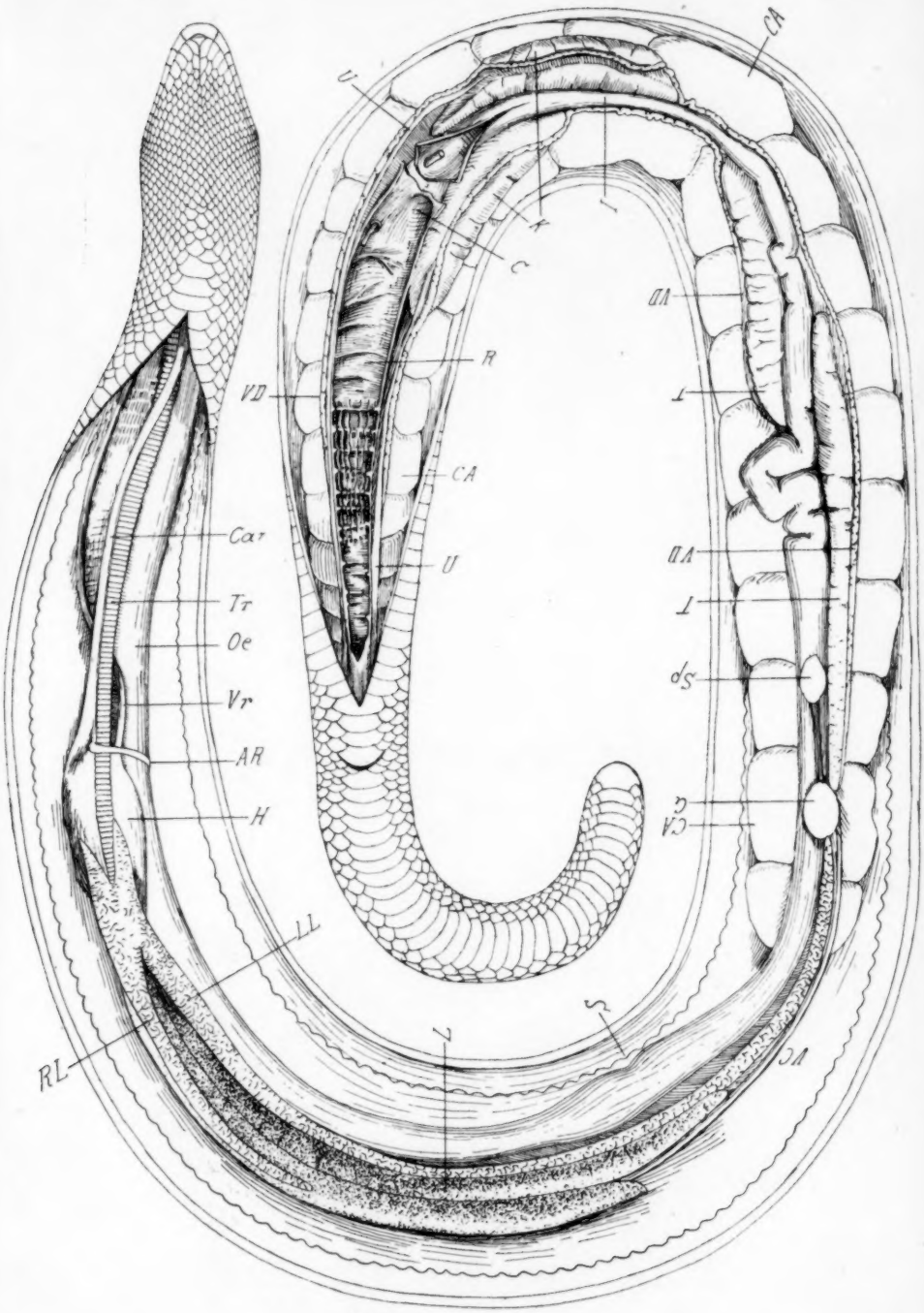
LETTERING.

Œ. Œsophagus; *St.*, Stomach; *I.*, Intestine; *R.*, Rectum; *C.*, Cœcum; *Tr.*, Trachea; *R. L.*, Right lung; *L. L.*, Left lung; *T. L.* Tracheal lung; *B. F.*, Bronchial foramen; *L.*, Liver; *G.*, Gall bladder; *K.*, Kidney; *U.*, Ureter; *T.*, Testis; *V. D.*, Vas deferens; *Oc.*, Ovary; *Od.*, Oviduct; *V.*, Vagina; *F.*, Fontanelle; *C. A.*, Corpus adiposum; *H.*, Heart; *A. R.*, Aorta root; *Car.*, Carotid; *J.*, Juglar vein; *V. C.*, Vina cavi.

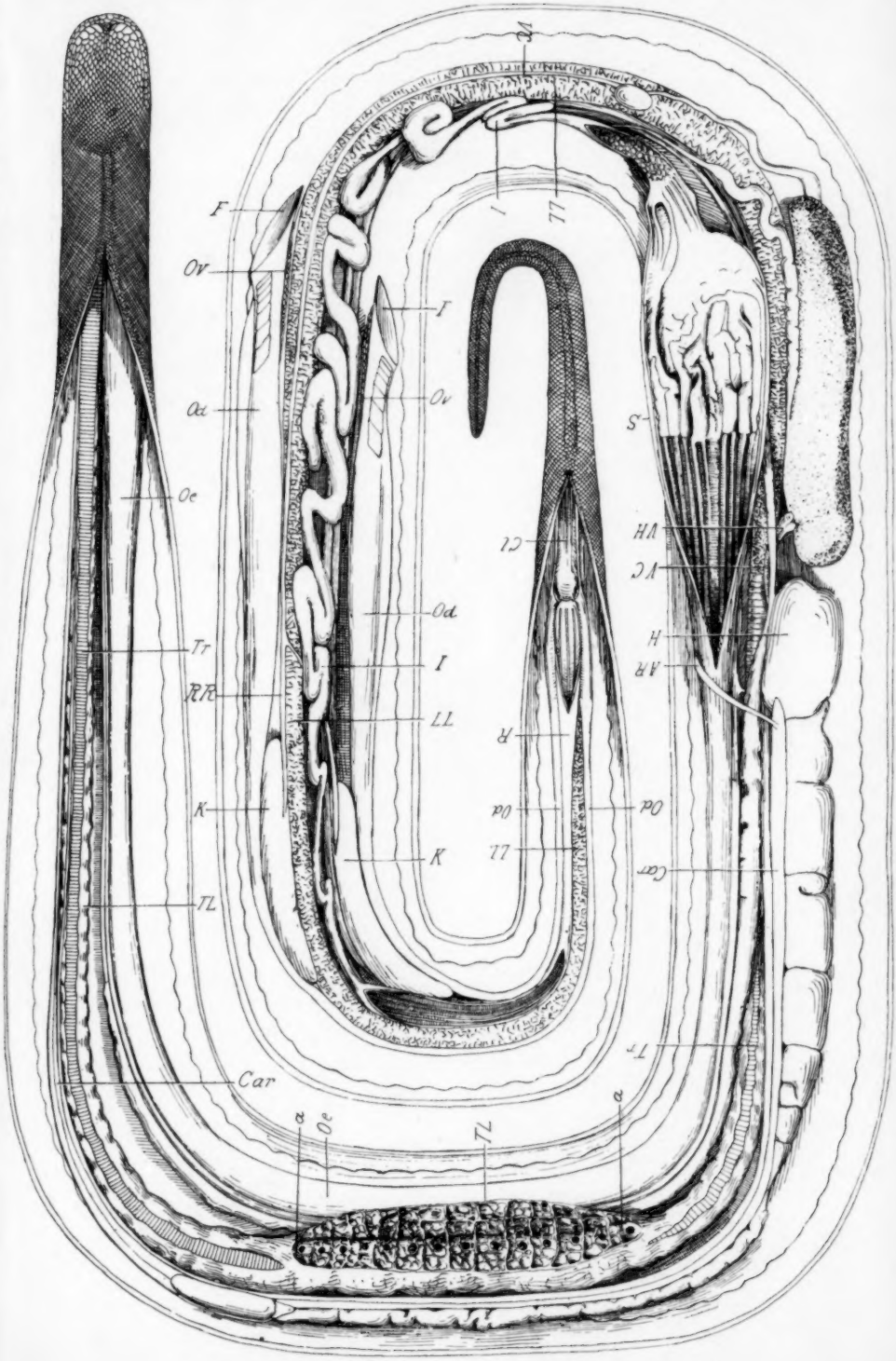


TYPHLOPS LIBERIENSIS HALLOW.

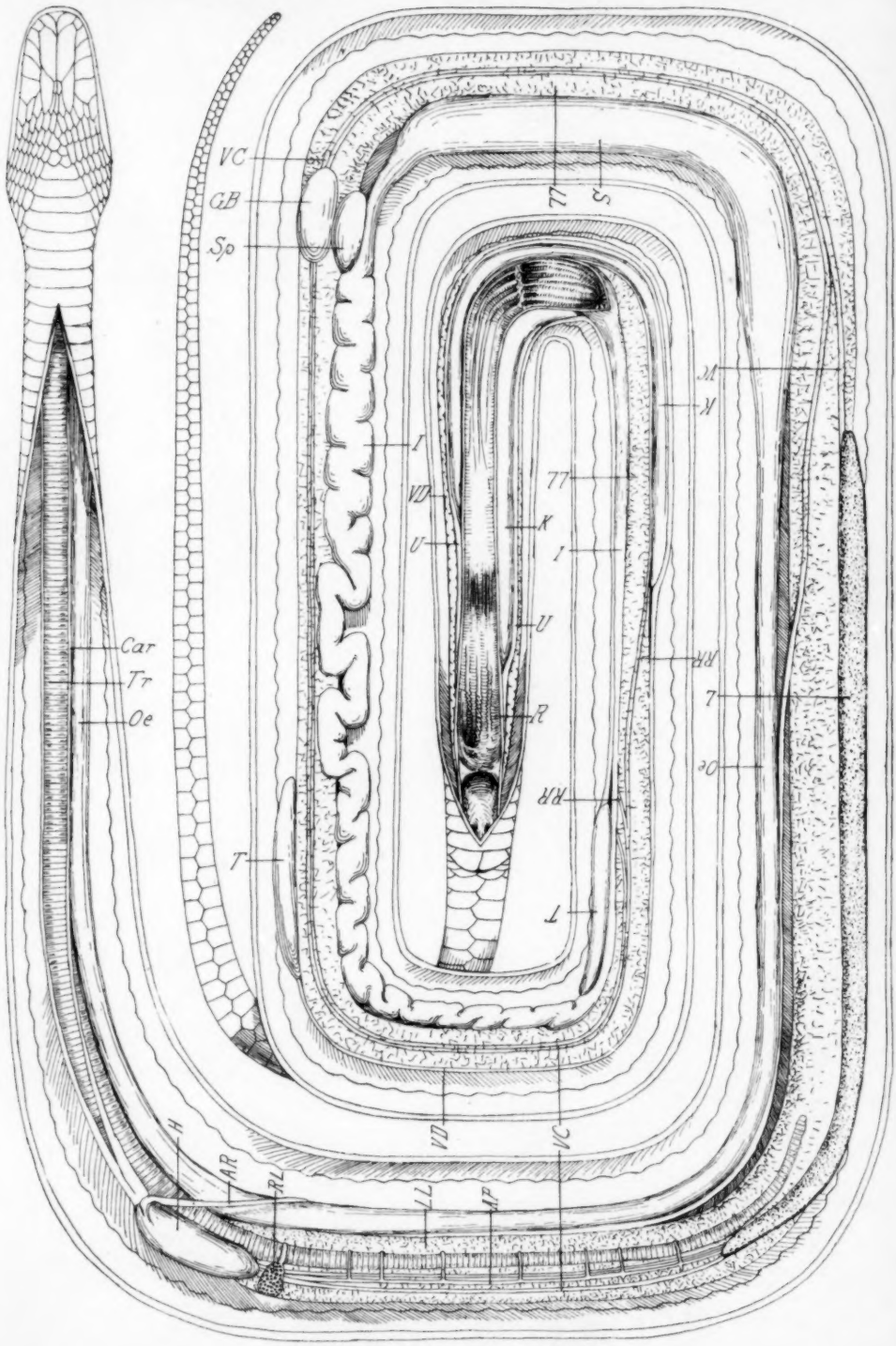




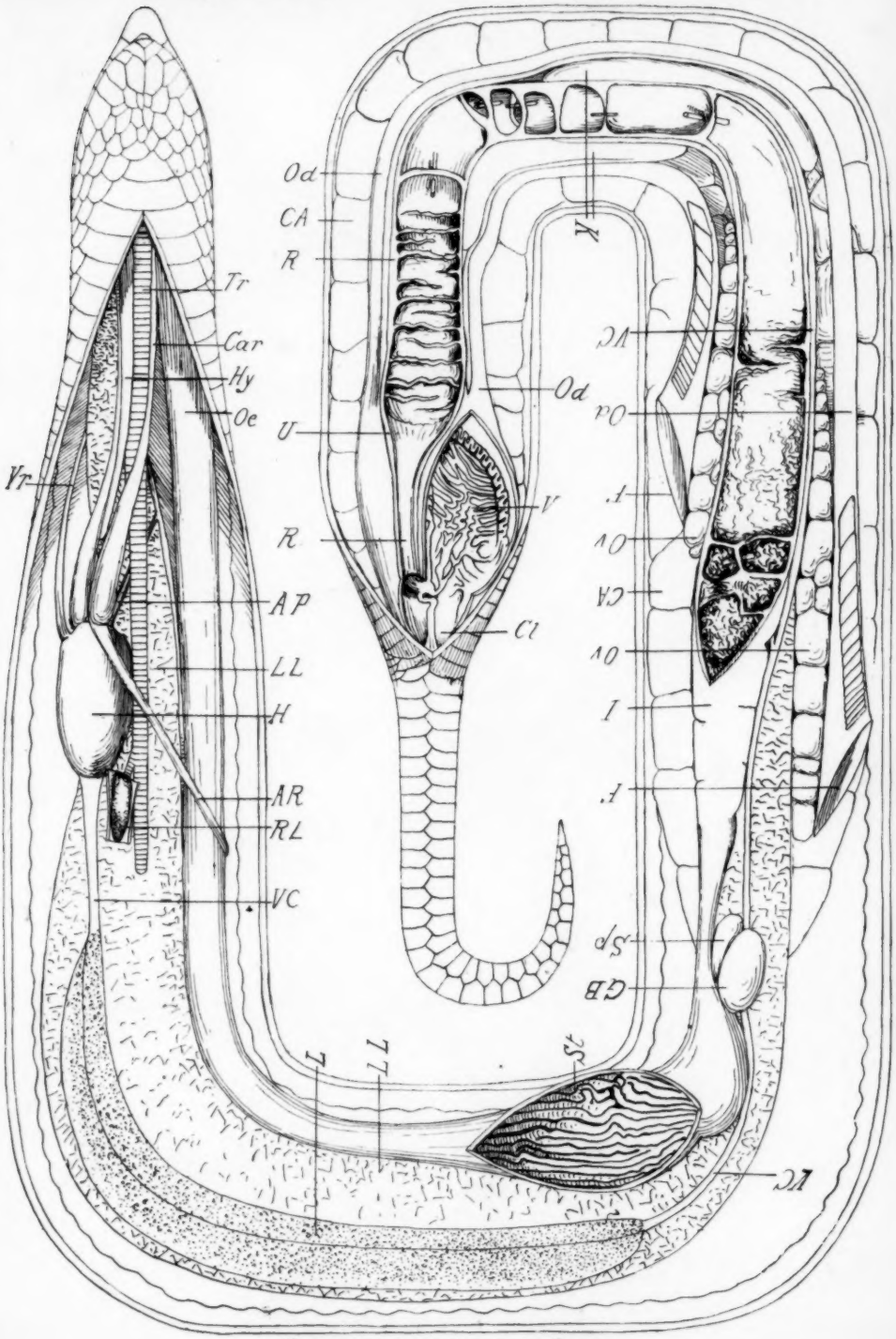
CHARINA BOTTÆ BLV.



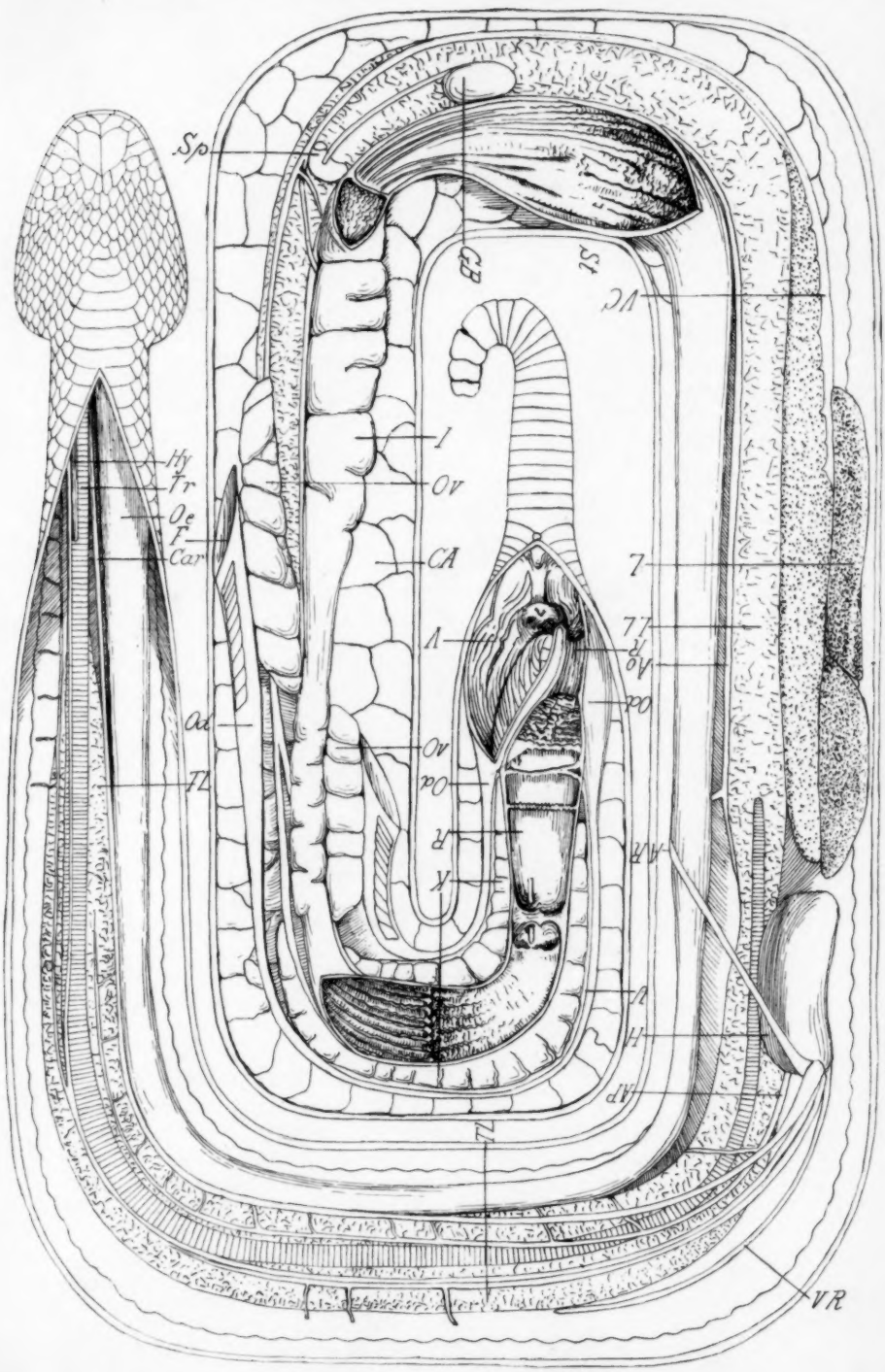
CHERSYDRUS GRANULATUS MERR.



COLUBER QUADRIVITTATUS HOLBR.



HETERODON PLATYRHINUS LATR.



CROTALUS CONFLUENTUS SAY.

A Comparative Study of the Chemical Behavior of Pyrite and Marcasite.

By Amos Peaslee Brown.

(Read before the American Philosophical Society, May 18, 1894.)

While much has been done in the way of investigating the chemical properties and constitution of the various artificial chemical compounds, comparatively little attention has been paid to the constitution of the naturally occurring chemical compounds. The carbon compounds, for instance, have in an immense number of cases been investigated with sufficient exactness to allow of our expressing their constitution by means of structural formulæ, but to how many minerals, aside from the simplest compounds, can we assign structural formulæ that are based on any knowledge that we possess of their reactions? It is true that much has been done in the way of the artificial production of minerals, and some knowledge of the constitution of certain minerals has been arrived at by a study of their decomposition products, but very little in comparison to the extent of the field. There are probably several reasons for this neglect of the study of the chemical properties and constitution of minerals, as want of homogeneity in the minerals themselves, difficulty of procuring or separating pure material for investigation, and similar difficulties which do not so frequently occur with artificial compounds. It thus happens that mineral chemistry is not as much studied as it deserves to be. Certain groups of minerals have, however, received some attention; for instance, Prof. F. W. Clarke has been carrying on a very interesting series of investigations on the constitution of certain silicates which have been productive of most valuable results. The natural sulphides, sulpharsenides and sulpho-salts present some very interesting problems in regard to their constitution, and it was with a view of adding to our knowledge of the chemical behavior of two of these sulphides that I undertook the series of investigations about to be described.

The compound FeS_2 is found in nature in two well-known forms—the one Pyrite (the isometric mineral) and the other Marcasite (the orthorhombic mineral). Since the separation of the two names from the general term, pyrites, it has been recognized that the orthorhombic form is lighter in color and also of lower specific gravity than the isometric form. From early times, also, the greater tendency of "white pyrites," or marcasite, to decompose in the air was well known.

Pyrite, the form which resists atmospheric weathering most thoroughly, is of a bright brass-yellow color and metallic lustre, breaking with an uneven conchoidal fracture, but bright on the surface of fracture. It crystallizes in the isometric system in forms showing generally pentagonal hemihedrism. Its specific gravity ranges from 4.8 to 5.2, averaging somewhat over 5. The brass-yellow crystals are generally quite unaltered in the air.

Marcasite, on the other hand, has a pale greenish or grayish yellow color, an uneven fracture, which shows a somewhat fibrous structure, and generally but little lustre on the surface of fracture. It crystallizes in the orthorhombic system, very commonly in twins or radiated fibrous masses. It is not very permanent in moist air, but readily decomposes and largely into $FeSO_4$. The chemical formula of either form, calculated from quantitative analyses, is the same, FeS_2 or $Fe = 46.67\%$, $S = 53.33\%$.

The chemical study of these two minerals has been mainly confined to the formation of one of them artificially and to a few experiments on their relative decomposability. Pyrite has been made artificially in a number of ways; marcasite has not as yet been formed artificially.* In 1836, Wöhler† produced cubes and octahedra of pyrite by subjecting a mixture of ferric oxide, flowers of sulphur and ammonium chloride to a temperature a little above the volatilizing point of the ammonium chloride. The resulting mass was washed to isolate the crystals from the accompanying pulverulent matter. Stanislas Meunier‡ modified this method by mixing equal parts of ferrous carbonate and sulphur and heating in glass tubes over a moderate flame. When the excess of sulphur has been driven off, there remains a black powder containing a considerable percentage of cubes of pyrite. Dana§ states that pyrite may be made "by slow reduction of ferrous sulphate in presence of some carbonate." Baubigny‖ produced FeS_2 as a crystalline crust by acting on metallic iron by a solution of SO_2 in water (H_2SO_3) in closed tubes and at a temperature of 200°. As neither this experiment nor the one immediately preceding it shows that the crystals were isometric, it is possible that both of them may be marcasite. Henri Saint Claire Deville¶ produced cubes of pyrite by melting a mixture of potassium sulphide (K_2S) and iron sulphide (FeS) in presence of excess of sulphur. This reaction, if correct as to the *cubical* product, is a remarkable one, as I should rather expect marcasite to result under such conditions. Senarmont** produced FeS_2 by decomposing a salt of iron by an alkaline sulphide at an elevated temperature in sealed glass tubes. The product was an amorphous black powder, not altering on exposure to air and not attacked by hydrochloric acid. This may have been pyrite, as marcasite is readily decomposed by moist air. Rammelsberg,†† in 1862, made FeS_2 pseudomorphs after ferric oxide (Fe_2O_3) by passing a current of hydrogen sulphide over it at a temperature between 100° and a red heat. The product of this reaction would likely be pyrite.

In nature it would seem that in most cases the sulphide of iron first

* Doelter, *Zeit. für Kryst.*, xi, 31, 1885; cf. Dana, *Syst. Min.*, 1892.

† *Pogg. Ann.*, xxxvii, p. 238.

‡ *Les Méthodes de Synthèse en Mineralogie*, S. Meunier, 1891.

§ J. D. Dana, *System of Mineralogy*, edition of 1868, p. 64.

‖ S. Meunier, *Synth. Min.*, p. 279.

¶ Cited in *Dict. Chem.* of Wartz, by E. Wilm, article "Iron," T. i, p. 1414.

** S. Meunier, *Synth. Min.*, p. 285.

†† *Jour. für Praktische Chemie*, T. lxxxviii, p. 266.

formed is FeS, but probably by action of a ferric salt, or carbonic acid (H_2CO_3), causing a loss in iron FeS_2 results, and this is almost always pyrite. On the other hand, where ferrous sulphate has been reduced by slow action of decomposing organic matter, the resulting sulphide seems to be generally marcasite, which if not in crystals may be recognized by its ready weathering to ferrous sulphate ($FeSO_4$). This compound may, however, in many cases, be a mixture of pyrite and marcasite, as much pyrite seems to be.* These several ways in which pyrite may be formed are of importance as indicating the condition of the iron in the compound, and will be referred to later on.

Equally important as bearing on the constitution of these sulphides are the observations that have been made as to their decomposition under atmospheric agencies. On exposing crystallized pyrite to atmospheric weathering it is generally found that but little, if any, change takes place even in a year's time, while crystallized marcasite, under the same conditions, shows a rapid weathering. The main product of the weathering of pyrite in nature is the compound limonite, $Fe_4O_3(OH)_6$, which occurs in large quantities in nature, evidently derived from pyrite. Its pseudomorphs after pyrite are very common. On the other hand, when marcasite weathers a very large percentage of ferrous sulphate ($FeSO_4$) is formed with a comparatively small percentage of limonite, unless the marcasite decomposes underground and under pressure, when limonite is largely produced.† Much of the excess of sulphur with marcasite is changed to sulphuric acid, but with pyrite much remains behind as sulphur. Some comparison of the rate of oxidation of these two minerals in the air is afforded by an examination of specimens in a collection. Here it will be found that most of the pyrite is unchanged, but nearly every specimen of marcasite will show tarnish if no other sign of oxidation, and often a considerable coating of oxide can be seen, or a white efflorescence of $FeSO_4$.

Chemical investigations of these two minerals have been mainly in the way of analysis, but some experiments have been made in the way of studying their relative behavior towards certain reagents. Before describing my experiments, it will be necessary to briefly mention some of these.

Both minerals are decomposed by a solution of silver nitrate and gold chloride, the decomposition taking place quite rapidly.‡ My experiments in this connection are mentioned later.

A. A. Julien § has shown that different samples of pyrite show a difference in their reaction with bromine vapor. His experiments consisted in exposing finely ground pyrite to the action of bromine vapor at the tem-

*Compare A. A. Julien, "Decomposition of Pyrite," *Ann. N. Y. Acad. Sci.*, Vols. iii and iv.

† Blum, *Pseudomorphosen*, 1843, pp. 197–199.

‡ S. Meunier, *Synth. Min.*, p. 309.

§ A. A. Julien, *Ann. N. Y. Acad. Sci.*, Vol. iv, pp. 151, 155.

perature of the air for twelve hours. The residue was extracted with dilute H_2SO_4, which removed the iron rendered soluble (bromide), and the iron was then determined in this solution. The percentage of iron that had dissolved varied from 2.43 to 15.20 per cent., although all samples tested are described as pyrite. He also tried the action of bromine in aqueous solution, but the reaction was too rapid to give any comparative results.

Much more important are the results obtained in the oxidation of these minerals by the electric current as conducted by Prof. Edgar F. Smith,* and it was the remarkable results that were then obtained that induced me to continue the study of the comparative reactions of these two minerals. Smith found that a current which would completely oxidize the sulphur in marcasite in a given time would oxidize less than half of the sulphur in pyrite in the same time. This remaining sulphur was held very tenaciously, though the mineral was subjected to more powerful currents and longer continued action than in the case of marcasite or pyrrhotite. Finally, by adding an equal quantity of CuO, and using a more powerful current, all of the contained sulphur was oxidized. Previous to the addition of CuO but 21 or 22 per cent of the sulphur was oxidized. In concluding the article above referred to the author questions whether the crystalline form alone can make this difference in the action of the two minerals when under the influence of the current.

The two samples of pyrite and marcasite that I selected for the following study were chosen after considerable examination of material as being typical of the two forms of FeS_2. The pyrite was from the hematite mines of Elba. It is exceptionally pure and free from decomposition or tarnish. Before deciding on it finally pieces were ground and polished and then examined under the microscope with powers ranging from 50 to 200 diameters, in order to see if it contained any enclosures or varied in texture. It was perfectly homogeneous and showed no enclosures. It took a high polish. The crystals showed the combination of octahedron and pentagonal dodecahedron $O + \frac{2}{2}\frac{2}{2}$. Some of the crystals were coated in places with scales of hematite, but this was all carefully removed in breaking up material for experiment. The color was bright brass-yellow, the specific gravity was determined as 5.179. The marcasite was from the zinc mines of the Subcarboniferous of Joplin, Jasper county, Mo., finely crystallized in polysynthetic twinnings. The freshly broken crystals show a greenish yellow color, almost white, but they tarnish readily with bluish or brownish colors. No gangue was present, everything dissolving completely in nitric acid. This marcasite was examined with the microscope in the same way as the pyrite; it did not take such a high polish on account of a fibrous structure, but no foreign matter was found with a power of 200 diameters. Its color was uniform throughout, showing that no pyrite was present. The specific gravity as determined was 4.844.

In preparing material for experiment only sufficient was ground for im-

Jour. Franklin Inst., Vol. cxxx, pp. 152–154.

mediate use to avoid any chance of oxidation of the ground material; the stock samples of the two minerals broken to nut size were kept in stoppered bottles. The grinding of material was continued as long as grit appeared, but no bolting was resorted to.

As the experiments of Prof. Smith on oxidation by the electric current showed such remarkable results, my first experiments were on oxidation. As an oxidizing agent potassium permanganate ($KMnO_4$) was used, several strengths of which were tried for varying intervals of time with each mineral, and the amount of sulphur oxidized to sulphuric acid determined in the liquid by precipitating as barium sulphate. The object was to secure a complete series of results which would show the comparative rates of oxidation of the sulphur in the two minerals. Neutral aqueous solutions of the potassium permanganate were used, and the strengths of solution employed were $\frac{1}{100}$ normal, one per cent., three per cent. and five per cent.; the periods of oxidation extending over one, two, three, four and five hours, and the entire series being performed at ordinary temperatures and at 100°. As duplicate determinations were made in the majority of cases (I made about 130 determinations of sulphur as barium sulphate), this work consumed a large amount of time and prevented as full a study of some other reactions of the two minerals as had been originally intended. The following are the detailed descriptions of my processes and results:

Action of $\frac{1}{100}$ Normal Potassium Permanganate Solution at Ordinary Temperature.

These oxidations were performed as follows: Two-tenths of a gram of the finely powdered mineral was placed in a stoppered bottle of about 100 c.c. capacity, then 50 c.c. of the permanganate solution added and the contents of the bottle violently shaken to break up lumps. This shaking was repeated about every fifteen minutes while the oxidation lasted. The temperature of the room was at the same time recorded. As stated, the oxidation was continued for one, two, three, four and five hours with each mineral, making at least ten experiments necessary for each strength of solution. After the solution had acted for the required time it was rapidly filtered through asbestos with aid of the filter pump, the filtrate transferred to a beaker, 20 c.c. of concentrated hydrochloric acid added, and the whole heated until all manganese was reduced to manganous chloride. If not too acid the solution was then diluted to about 300 c.c. and the sulphuric acid precipitated as barium sulphate. When very acid, excess of hydrochloric acid was removed by evaporation or by adding ammonia, the ammonium chloride seeming to facilitate the precipitation. The precipitate was washed with hot water and then weighed. All precipitations were made at boiling temperature and digested hot for at least two hours, and then cold for at least twelve hours more before filtering. The filtrates from most of the cold tests were re-

duced with metallic zinc and titrated with permanganate, but no iron was found in the solution.

The two minerals did not present the same appearance when acted on by the oxidant. Pyrite retained its color and seemed as pulverulent as when the permanganate was added, but marcasite immediately on the addition of the reagent became coated with manganese dioxide, took on a brownish color, and showed a tendency to cake together and stick to the sides of the bottle, so that it was with difficulty dislodged. This tendency of the marcasite was more marked with stronger solutions of the permanganate and was doubtless the cause of much of the irregularity that will be noticed in the results. The reason for this difference in action of the reagent on the two minerals will be discussed later on.

The percentages of sulphur oxidized in the two minerals by this method are shown in the following table, where all results that were obtained are recorded. The figures show the percentages of sulphur oxidized, calculated on the basis of FeS_2 equal to one hundred per cent. It will be noted that the four-hour oxidation of marcasite shows a result that is less than the two-hour. This was due to caking of the mineral against the walls of the bottle, which prevented much of it from coming in contact with the solution. On the whole, this series was about the most satisfactory of the cold experiments with $KMnO_4$, the action of this dilute solution being less rapid and hence more even than that of the more concentrated solutions; naturally the action ceases with a certain dilution, and hence the four- and five-hour oxidations of pyrite are about equal.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a $\frac{1}{100}$ N. Solution of $KMnO_4$ at 22°.

Mineral.	1-Hour.	2-Hour.	3-Hour.	4-Hour.	5-Hour.
Pyrite with $\frac{1}{100}$ N. solution $KMnO_4$	.78	1.17	1.38	1.74	1.72
Marcasite with $\frac{1}{100}$ N. solution $KMnO_4$	1.07	1.86	2.04	(1.25)	2.38

The curves formed by plotting these results on rectangular coördinates are shown in Pls. xvii and xviii. They are marked 22° M_1 for the marcasite and 22° P_1 for the pyrite.

Action of 1 Per Cent. Potassium Permanganate Solution at Ordinary Temperature.

This and also the two following series were performed as described under $\frac{1}{100}$ normal solution above. At least two experiments were tried with each mineral in this and the two following cold oxidations, and whenever a result was notably higher or lower than its dupli-

cate a third or fourth was tried. The tendency of the marcasite to cake, noted in the previous series, became still more marked here, and is doubtless the cause of one of the four-hour oxidations (marked by parenthesis) being notably lower than the three-hour. Such a result is obviously incorrect. On the other hand, the result in the three-hour column which is placed in parenthesis is the highest obtained. This experiment was made at the same time as the one showing 1.93 per cent., but the room was very warm (25°), which may in part account for this high result. It will be noticed that the oxidation of the pyrite seems to stop at the three-hour trial, those following showing no appreciable increase. This is well seen in the graphic representation of these oxidations (Pls. xvii and xviii).

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 1 Per Cent. Solution of $KMnO_4$ at 22°.

Mineral.	1-Hour.	2-Hour.	3-Hour.	4-Hour.	5-Hour.
Pyrite with 1 per cent. solution $KMnO_4$ cold.	1.72 1.71	1.38 1.47	1.85 1.87	1.79 1.90	1.70 1.89
Marcasite with 1 per cent. solution $KMnO_4$ cold.	1.16 1.28	1.29 1.13	1.93 2.19 (3.92)	1.95 (1.56) 2.69	2.01 2.15 2.55

Action of 3 Per Cent. Solution of Potassium Permanganate at Ordinary Temperature.

The conditions of this series of experiments were the same as those of the last. The tendency of the results to fluctuate instead of showing a gradual progression is now very marked. One of the one-hour pyrite oxidations shows more sulphur oxidized than is shown by any other individual result of the series. No explanation can be offered for such a discrepancy as this. On the other hand, the high result shown in the three-hour oxidation is quite easily explained by the marcasite having been little, if any, caked in this experiment. The two low results of pyrite three-hour and marcasite four-hour oxidations are readily explicable on the ground of caking of the material. As the barium sulphate was often determined several days after the oxidation was completed, it is obvious that no reliable notes could be made concerning the caking or non caking of the mineral in the permanganate. With this strength of solution it is evident, too, that the main action of the permanganate is complete at the end of one hour, notably in the case of the marcasite, and it is only when very vigorous agitation exposes fresh surfaces of the mineral to the action of the $KMnO_4$ that any further action can take place. We therefore see that marcasite in one hour gives up as much sulphur as in five hours, and this is very graphically shown on Pl. xvii.

PROC. AMER. PHILOS. SOC. XXXIII. 145. 2 D. PRINTED JUNE 18, 1894.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 3 Per Cent. Solution of $KMnO_4$ at 22°.

Mineral.	1-Hour.	2-Hour.	3-Hour.	4-Hour.	5-Hour.
Pyrite with 3 per cent. solution $KMnO_4$ cold.	1.65 (3.55)	2.23 2.31	2.80 (1.58)	2.47 2.62	2.81 2.28
Marcasite with 3 per cent. solution $KMnO_4$ cold.	2.72 2.87	2.17 2.33	2.87 (3.31)	2.88 (1.89)	2.83 2.77

Action of 5 Per Cent. Solution of Potassium Permanganate at Ordinary Temperature.

In this series, as in the last, the action, as far as pyrite was concerned, was practically complete at the expiration of the first hour, but in the case of the marcasite this point was not reached until probably the end of the second hour, and, in fact, in one case was progressive to the end. But one very great discrepancy is to be noted here in the three-hour column with marcasite. The low result in the next column is explained by caking.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 5 Per Cent. Solution of $KMnO_4$ at 22°.

Mineral.	1-Hour.	2-Hour.	3-Hour.	4-Hour.	5-Hour.
Pyrite with 5 per cent. solution $KMnO_4$ cold.	2.39 3.15	3.03 3.15	3.22 2.32	2.89	2.79 3.24
Marcasite with 5 per cent. solution $KMnO_4$ cold.	2.10 2.52	3.06 3.76	3.82 (5.83) 2.77	3.16 (2.44)	3.39 4.17

This series finishes the experiments at ordinary temperatures. In all of them the action was comparatively slight, not exceeding at most 10 per cent. of the contained sulphur in the mineral which would not be sufficient to show any marked difference between the two minerals as bearing on their constitution, if the constitution which seems to be indicated by subsequent experiments (to be presently described) is the true one.

The oxidations with potassium permanganate at a temperature of 100° were conducted by suspending the vessel containing the mineral and solution in boiling water. Both stoppered bottles and thin glass flasks closed with perforated corks were used for this series of experiments. The water was kept continually boiling and the bottles or flasks were immersed deep enough to cover that portion of them containing the permanganate. Six or eight oxidations were made at one operation. The

permanganate solution, after it had acted the required time, was treated as in the experiments conducted at ordinary temperatures described above. Much more active oxidation took place at this temperature (100°), but the tendency of the mineral to cake together was much more marked, and now this took place with pyrite as well as with marcasite. Moreover, the deposition of manganese dioxide in every case was now very great, causing often a stoppage of the oxidation until it could be dislodged. As these oxidation experiments had already occupied much time only one trial was now made at each concentration of solution for each hour from one to five, unless, as before, marked discrepancies occurred, when two or more trials were made. The series of results are hence not so regular as they would have been had more trials been made, these irregularities arising from the difficulties that have been mentioned, as well as from the fact that the dilute solutions soon became exhausted, and that all solutions suffered some evaporation, but some more than others, causing irregular strength with the same solution. Nevertheless, the results agree in kind with those obtained at ordinary temperature, but differ widely in degree. Whereas at ordinary temperature the greatest amount of sulphur oxidized in marcasite by the five-hour trial with 5 per cent. permanganate was 4.17 per cent., at 100° this became 16.36 per cent, or about four times as much.

ACTION OF $\frac{1}{100}$ NORMAL POTASSIUM PERMANGANATE SOLUTION AT 100°.

The results given in the following table show perhaps more strongly than either of the other series of experiments at 100° the effect of the different disturbing causes that have been mentioned. It especially shows the effect of caking of the pyrite, which now came in as an important disturbing factor. The result of this caking is shown in the three- and four-hour results with pyrite, both being very low. Marcasite, on the other hand, invariably caked and stuck to the bottom of the bottle, but as this was a constant source of error in this case, the results show a gradual and fairly even increase. Irregular results with marcasite were now largely conditioned by the evaporation of the solution or by the fact of whether the mineral was evenly caked over the inner surface of the vessel or concentrated in spots. The result of this latter way of caking will be better seen in some of the subsequent series of experiments.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a $\frac{1}{100}$ Normal Solution of $KMnO_4$ at 100° C.

MINERAL.	1-HOUR.	2-HOUR.	3-HOUR.	4-HOUR.	5-HOUR.
Pyrite with $\frac{1}{100}$ N. $KMnO_4$ at 100° C.....	4.05	4.72	3 36	2.04	5.64
Marcasite with $\frac{1}{100}$ N. $KMnO_4$ at 100° C.....	3.17	3.84	3.76	5.63	5.61

ACTION OF 1 PER CENT. POTASSIUM PERMANGANATE SOLUTION AT 100°.

The results of the oxidation shown in this series are chiefly remarkable as still further illustrating the action of the solution on the caked material, as shown in the four- and five-hour trials with pyrite and the four-hour trial with marcasite. This latter shows, too, the effect of having the caked mineral massed in one spot. With this exception, the marcasite oxidations are progressive and fairly uniform (the two hour trial falls somewhat below what it doubtless should be), but the pyrite shows a sharp fall in the four- and five-hour trials. The cause of this has been indicated. That the concentration of the solution by evaporation caused an increase in the action seems to be indicated by the result of the five-hour marcasite oxidation, but this is much more strongly marked in the 5 per cent. series in the case of pyrite, which will be referred to later on.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 1 Per Cent. Solution of $KMnO_4$ at 100°.

MINERAL.	1-HOUR.	2-HOUR.	3-HOUR.	4-HOUR.	5-HOUR.
Pyrite with 1 per cent. $KMnO_4$ at 100° C.	6.03	6.98	8.38	6.11	6.88
Marcasite with 1 per cent. $KMnO_4$ at 100° C.	6.43	5.61 6.25	8.56	7.40	9.10

ACTION OF 3 PER CENT. SOLUTION OF POTASSIUM PERMANGANATE AT 100° C.

The average results of this series of oxidations were very good, with the exception of two members of the series—the marcasite five-hour trial and the pyrite three-hour. This latter was repeated, but with a similar low result. Leaving these two out of account, the average results show a very fairly even rate of progression, which have been brought out in the diagram (Pl. xvii). It is evident from an inspection of the following table that the marcasite oxidations of the four- and five-hour trials were arrested by some disturbing influence.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 3 Per Cent. Solution of $KMnO_4$ at 100° C.

MINERAL.	1-HOUR.	2-HOUR.	3-HOUR.	4-HOUR.	5-HOUR.
Pyrite with 3 per cent. $KMnO_4$ at 100° C.	5.52 (7.01)	5.77 7.89	6.81 5.16	10.73	11.08
Marcasite with 3 per cent. $KMnO_4$ at 100° C.	5.25 5.50 (8.67)	7.97	9.42	9.80	7 55

Action of a 5 Per Cent. Potassium Permanganate Solution at 100° C.

This series was decidedly the most satisfactory of the experiments conducted at 100° and, with the exception of the two-hour oxidations, in case of each mineral shows a remarkably regular increase in the oxidation of the sulphur. It illustrates, too, in the case of the pyrite, the effect of the concentration of the solution due to evaporation. This causes a more rapid rise in the results after three hours' action, and notably between four and five hours. This rise is not so well seen from the table as from the plot of the results given in Pl. xvii. Here this rising of the curve after three hours is very marked as contrasted with the curve of the marcasite oxidations.

Table Showing the Relative Oxidation of Sulphur in Pyrite and Marcasite by a 5 Per Cent. Solution of $KMnO_4$ 100°.

Mineral.	1-Hour.	2-Hour.	3-Hour.	4-Hour.	5-Hour.
Pyrite with 5 per cent. $KMnO_4$ at 100° C.....	7.95	7.52	9.85	11.86	14.98
Marcasite with 5 per cent. $KMnO_4$ at 100° C.....	8.38	8.38	13.27	14.85	16.36

The graphic representation of the rate of oxidation of sulphur in these two minerals is plotted from the following tables, the first of which shows the average amounts of oxidation of sulphur compiled from the several small tables already given. In this compilation I have omitted a few of the results given in parentheses in the small tables as they are evidently incorrect, and would vitiate the averages. On the other hand, I have simply retained the parentheses of the small tables in certain cases where but one result was obtained. The second table, also compiled from the several small tables, shows for the experiments at ordinary temperature the result of selecting, wherever possible, such individual determinations as show a progressive increase in the oxidation. In this way more regular series of results are obtained. Inasmuch as the variations are so marked, this method of selecting results seems justified, at least for obtaining a comparison of the relative rates of oxidation of the sulphur in the two minerals. The results of Table i are plotted in Pl. xvii, and those of Table ii in Pl. xviii.

I. *Table Showing Average Relative Oxidation of Sulphur in Pyrite and Marcasite by Solutions of $KMnO_4$ at 22° and at 100°.* See Pl. xvii.

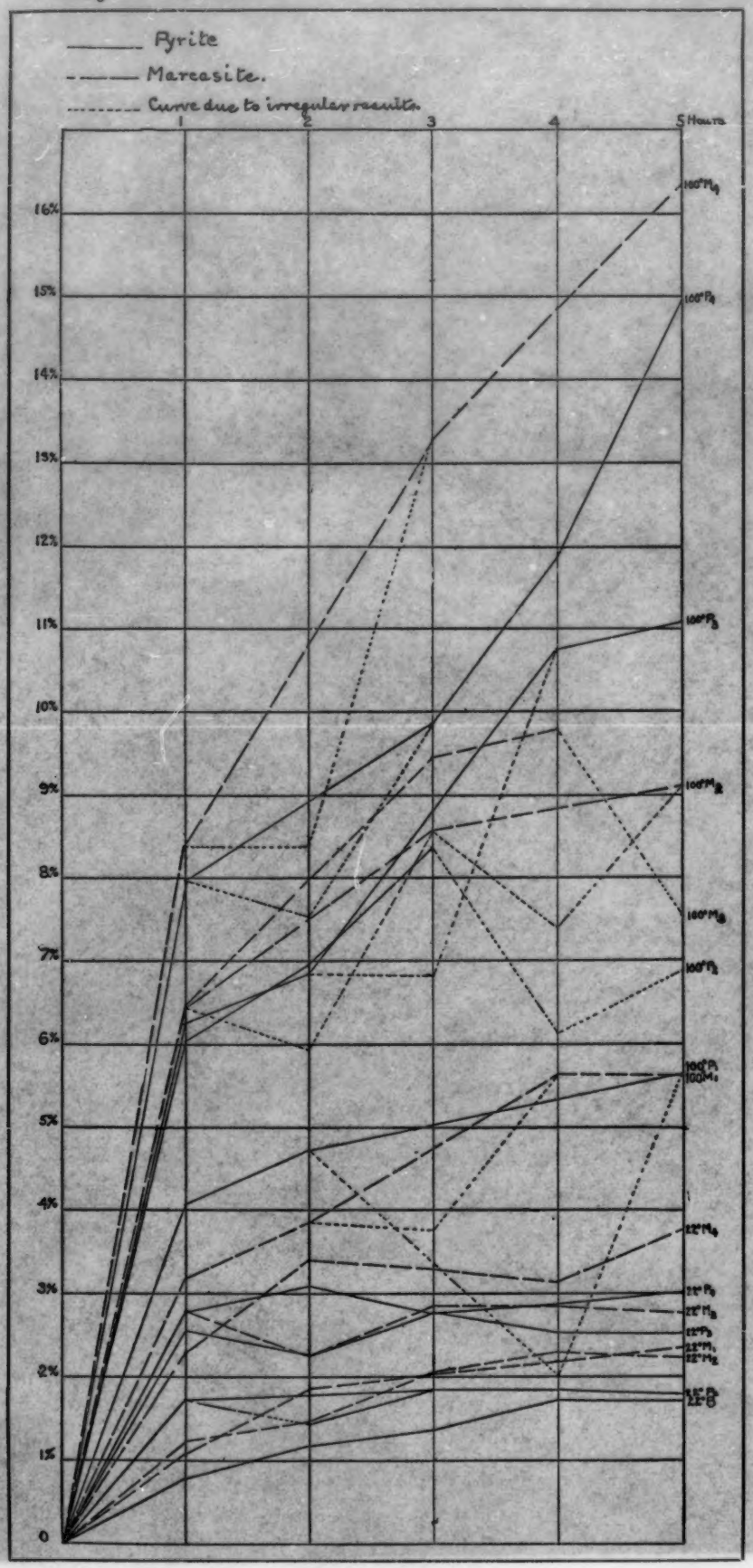
Mineral.	1-Hour	2-Hour	3-Hour	4-Hour	5-Hour	On Pl.
Pyrite $\frac{1}{100}$ N. cold	.78	1.17	1.38	1.74	1.72	22° P_1
Marcasite $\frac{1}{100}$ N. cold	1.07	1.86	2.04	(1.25)	2.38	22° M_1
Pyrite 1 per cent. cold	1.71	(1.43)	1.86	1.85	1.80	22° P_2
Marcasite 1 per cent. cold	1.22	1.21	2.06*	2.32*	2.24	22° M_2
Pyrite 3 per cent. cold	2.55	2.27	2.80*	2.55	2.55	22° P_3
Marcasite 3 per cent. cold	2.80	2.25	2.87*	2.88*	2.80	22° M_3
Pyrite 5 per cent. cold	2.77	3.09	2.77	2.89	3.02	22° P_4
Marcasite 5 per cent. cold	2.31	3.41	3.30*	3.16	3.78	22° M_4
Pyrite $\frac{1}{100}$ N. 100°	4.05	4.72	3.36	2.04	5.64	100° P_1
Marcasite $\frac{1}{100}$ N. 100°	3.17	3.84	3.76	5.63	5.61	100° M_1
Pyrite 1 per cent. 100°	6.03	6.98	8.38	6.11	6.88	100° P_2
Marcasite 1 per cent. 100°	6.43	5.93	8.56	7.40	9.10	100° M_2
Pyrite 3 per cent. 100°	6.26	6.83	6.81*	10.73	11.08	100° P_3
Marcasite 3 per cent. 100°	6.47	7.97	9.42	9.80	(7.55)	100° M_3
Pyrite 5 per cent. 100°	7.95	7.52	9.85	11.86	14.98	100° P_4
Marcasite 5 per cent. 100°	8.38	8.38	13.27	14.85	16.36	100° M_4

II. *Table Showing Selected Results of the Oxidation of Sulphur in Pyrite and Marcasite by Solutions of $KMnO_4$ at 22°.* See Pl. xviii.

Mineral.	1-Hour	2-Hour	3-Hour	4-Hour	5-Hour	On Pl.
Pyrite $\frac{1}{100}$ N. cold	.78	1.17	1.38	1.74	(1.72)	22° P_1
Marcasite $\frac{1}{100}$ N. cold	1.07	1.86	2.04	(1.25)	2.38	22° M_1
Pyrite 1 per cent. cold	(1.71)	1.47	1.85	1.90	1.89	22° P_2
Marcasite 1 per cent cold	1.16	1.29	1.93	1.95	2.15	22° M_2
Pyrite 3 per cent. cold	(1.65)	2.31	2.80	(2.62)	2.81	22° P_3
Marcasite 3 per cent. cold	(2.72)	2.33	2.87	2.88	2.83	22° M_3
Pyrite 5 per cent. cold	2.39	3.03	3.22	(2.89)	3.24	22° P_4
Marcasite 5 per cent. cold	2.52	3.06	3.82	(3.16)	4.17	22° M_4

In plotting from these tables a vertical scale of one-half inch per one per cent. of sulphur oxidized and a horizontal scale of three-quarters inch per hour of oxidation have been employed. Wherever there was a drop in the results the gap has been bridged over by the main curve, thus making the curves as nearly as possible progressive, but the drop has been plotted in fine dotted lines. On examining these curves the points as to the relative rates of oxidation that have been mentioned are shown very graphically, the curve of the marcasite oxidation rising in each case above the corresponding one of pyrite, but both showing a similar form. Of these curves the $\frac{1}{100}$ normal solution cold and the 5 per cent. solution hot

* Obtained by omitting discordant results.



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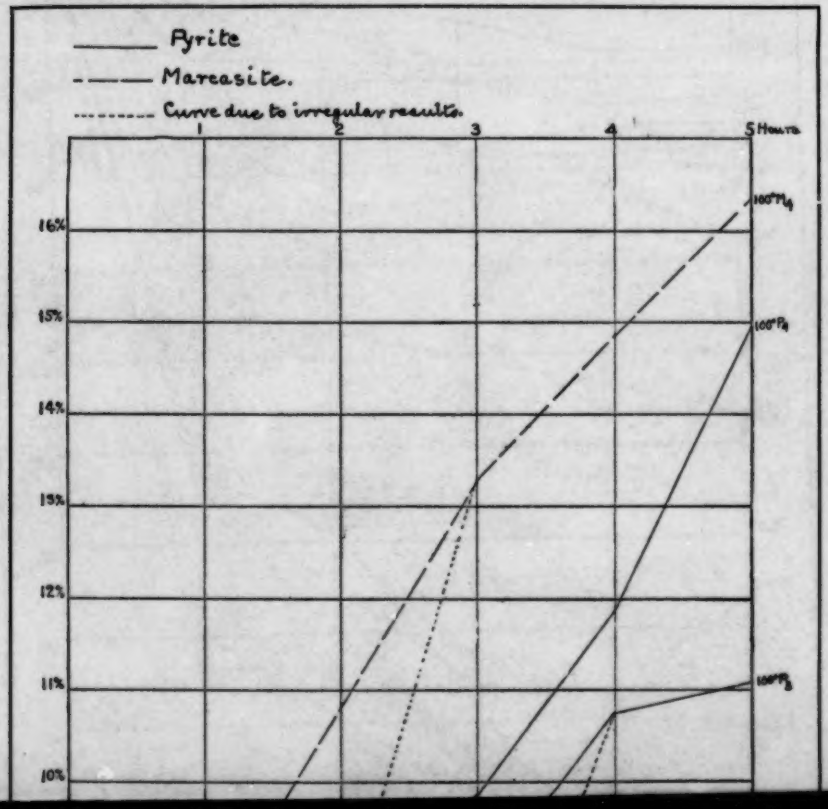
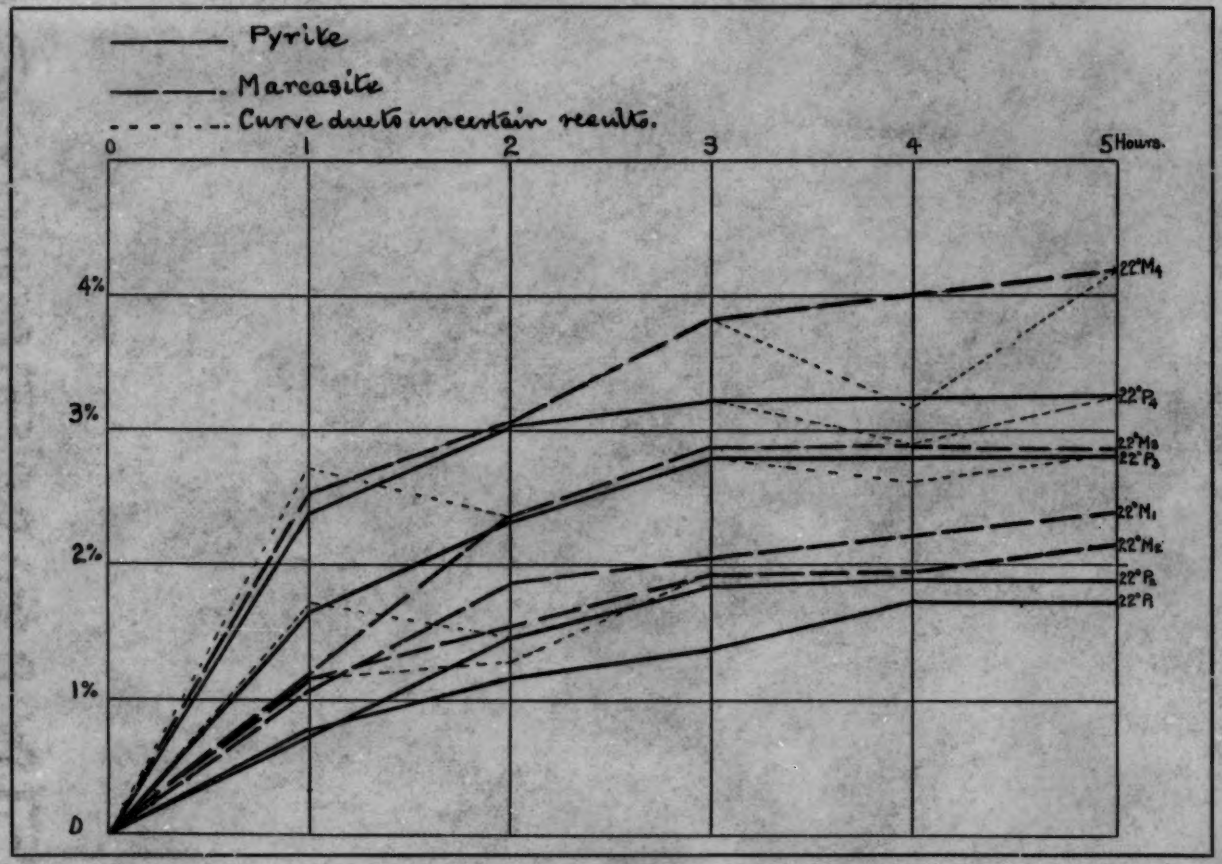

Pyrite
Marcasite.
Curve due to irregular results.
1
2
3
4
5 Hours
16%
15%
14%
13%
12%
11%
10%



Proceedings Amer. Philos. Soc. Vol. XXXIII, No. 145. Plate XVIII.

Pyrite
Marcasite
Curves showing variation of resistance.
Ohms
0
4
8
12
16
1
2
3
4

are the most regular. No very marked difference in the rate of oxidation is brought out by this series of experiments, the amount of sulphur oxidized never having reached the critical point in pyrite, as shown by Prof. Smith's oxidations with the current already described. This point at which the rate of oxidation of sulphur in pyrite suffers a change was found by Prof. Smith to be between 21 and 22 per cent. from the results of a very large series of current oxidations.* The explanation for this being the critical point in the oxidation of pyrite will be given in the discussion of its constitution. The experiments with permanganate oxidation simply show then that up to near this point (the highest point reached in the pyrite oxidation was nearly 15 per cent.) the relative rates of oxidation of the two minerals do not differ widely from each other, but that marcasite oxidizes somewhat faster than pyrite. This is simply what has been long known and recognized in regard to atmospheric weathering.

As will be seen when the constitution of these minerals is considered, marcasite cannot have a critical point in regard to oxidation of its sulphur.

The experiments thus far described had for their object the removal of sulphur. On the other hand, a number of ways of attacking the iron were tried and with more interesting results. In these trials reagents were selected which would attack the iron more energetically than the sulphur. Among these may be classed the experiments of solubility in acids.

Hydrochloric acid (hot or cold, concentrated or dilute) has little action on these minerals. Pyrite was treated for one hour with boiling concentrated HCl, of specific gravity 1.20 in covered beakers, and showed in the solution only 2.56 per cent. of iron out of 46.67 per cent. Marcasite, treated in the same way, gave an identical result. Similar experiments at the ordinary temperature were tried with both minerals, by digesting for three days with excess of concentrated hydrochloric acid and with excess of $2\,HCl + 3\,H_2O$, but even after three days the action was very slight in both cases. Pyrite gave with both concentrated and dilute acid the same result—a solution of 1.51 per cent. of iron. Marcasite gave almost identical results. The concentrated hydrochloric acid solution showed 1.51 per cent. of iron, the dilute solution 1.89 per cent. No evolution of hydrogen sulphide was detected by lead paper in either case. Concentrated sulphuric acid at boiling temperature decomposes both minerals, with evolution of sulphur dioxide and the separation of sulphur, but the action is very slow and seems to take place more readily with pyrite than with marcasite. Pyrite digested with concentrated sulphuric acid at boiling temperature for one hour showed 14.81 per cent. of the iron dissolved, but marcasite under like conditions was only attacked in one hour to the extent of 12.77 per cent. of iron. Trials were also made in the cold, but did not differ materially from the results obtained with HCl.

More important results were obtained by conducting dried hydrochloric

* Private communication from Prof. E. F. Smith, 1893.

acid gas over the minerals at an elevated temperature. In these trials, 0.2 gram of the mineral was placed in a porcelain boat and heated in a glass tube in a strong stream of the gas. The sulphur in the series of experiments at the lower temperature was collected by passing the gas through bulbs containing Br + HCl; at the higher temperatures, the residue in the boat was analyzed and the sulphur lost estimated by difference. In the experiments at low temperature the entire tube was exposed to a temperature of 210°, as determined by thermometer. The HCl was passed over in a strong stream for one hour. The action at this temperature was slight; the results obtained do not, however, show the entire amount of sulphur removed, as some remained in the cool end of the tube, from the dissociation of the hydrogen sulphide. As the action was so slight, no attempt was made to collect and estimate this sulphur remaining in the tube. In the bromine and hydrochloric acid solution was found sulphur as follows:

Pyrite at 210° in current of HCl (*a*)	0.94
" " " " (*b*)	0.93
Marcasite at 210° in current of HCl (*a*)	0.77
" " " " (*b*)	0.59

More marked results were obtained by increasing the temperature. Similarly conducted experiments were carried out at 310° and 325°, the time of heating ranging from one to three and one-half hours. The temperature of 310° was graded by keeping it between the melting points of $NaHSO_4 \cdot H_2O$ (300°) and $NaNO_3$ (313°), the higher temperature was between the last 313° and the melting point of $KClO_3$ (334°). After the HCl had been passed for a sufficient length of time, the tube was allowed to cool (with the gas current continued until cold) and then the remaining sulphur estimated by oxidizing the contents of the boat with nitric acid and potassium chlorate and precipitating and weighing as $BaSO_4$. The amount found, subtracted from 53.33 %, gave the loss of sulphur. In this case the results obtained by oxidation were reversed, the pyrite lost more sulphur than the marcasite. This is an expression of the fact that the hydrochloric acid gas (or its contained Cl) acts more vigorously on the iron of pyrite than on that of marcasite. The results of the reaction were in each case ferrous chloride in the boat and free sulphur in the tube, the latter from dissociation of the hydrogen sulphide. No ferric chloride was seen in the tube, except a trace with the pyrite. Each mineral was heated for one hour at 310° in a current of the gas and showed loss of sulphur as follows:

Pyrite heated at 310° for 1 hour in HCl, sulphur lost	10.73
Marcasite " " " " "	7.19

About the same relative amounts were lost on heating for three and one-half hours at 325°. The results thus obtained were as follows:

Pyrite heated at 325° for 3½ hours in HCl, sulphur lost	17.13
Marcasite " " " " "	10.70

Besides these two experiments, pyrite was heated for one hour at a red heat in a stream of the gas. A copious sublimate of ferrous chloride was found in the tube, with a trace of ferric chloride and sulphur. This time the loss was 46.47 per cent. of sulphur. It seems evident from these experiments that, as above stated, the iron in pyrite is in a condition that is more readily acted on by hydrochloric acid than is the iron in marcasite. It will be proved that the iron in marcasite is all ferrous, while part of that in pyrite is ferric, and this is probably the explanation of the above phenomenon. All of the iron in each case described above would form ferrous chloride ($FeCl_2$) on account of the reducing action of the hydrogen sulphide formed. Under the conditions of the above experiments, the critical point developed in the oxidation of pyrite was not reached, but it is not likely that it exists with this reagent, or if there be a critical point it is not 21 per cent. The thought suggested itself to me that perhaps some sulphur would be lost in pyrite if it were heated to 325° in a neutral atmosphere, and that this might account for the difference shown in the loss of sulphur in the two minerals. This proved not to be the case. Pyrite heated in this way in an atmosphere of nitrogen gave no appreciable loss after one hour at a temperature of 325°.

Instead of hydrochloric acid gas, the action was tried of ammonium chloride at temperatures up to 335° and in an atmosphere of nitrogen. Under these conditions the sulphur was combined as ammonium sulphide probably and did not exert such a reducing action on the iron. These experiments were conducted as follows: 0.2 gram of the finely pulverized mineral was mixed with 0.5 gram dry ammonium chloride and introduced (in a porcelain boat) into a glass tube. Test samples of $NaHSO_4 \cdot H_2O$ and $KClO_3$ in sealed tubes were used to regulate the temperature. All air was displaced in the tube by nitrogen and a slow current of nitrogen passed through the tube before heating. Under these conditions with marcasite, sulphur and ammonium sulphide were found sublimed in the tube along with ammonium chloride, and in the boat there was found much ferrous chloride without any ferric chloride, but in the case of the pyrite there was formed a large proportion of ferric chloride, which sublimed on the tube towards the end of the operation. The heating was conducted slowly in each case and continued until all ammonium chloride was sublimed from the boat, the temperature of 335° not being exceeded during this time. The entire operation lasted about twenty-five minutes in each case. Three trials of each mineral were made and with the same result in each case; with marcasite only ferrous chloride was found in the boat and no iron in the tube, pyrite always gave much ferric chloride and little ferrous. The amounts of sulphur removed are probably not very significant; they showed the following results:

Pyrite	heated	with	NH_4Cl	lost sulphur (*a*).....	7.02
"	"	"	"	(*b*).....	7.10
Marcasite	"	"	"	(*a*).....	9.50

PROC. AMER. PHILOS. SOC. XXXIII. 145. 2 E. PRINTED JUNE 19, 1894.

The important point brought out in these experiments is that pyrite contains a large amount of ferric iron, while in marcasite the iron apparently exists in the ferrous condition. Some reducing action might, however, have taken place, due to the sulphides formed. The condition of the iron in the chlorides found in the boat and tube was very carefully tested by several reagents in each case, and there can be no doubt as to the correctness of the results as stated above.

The decomposition of the sulphides by metallic salts seemed to offer some hope of being productive of results that would show in a quantitative way the exact amounts of ferrous or ferric iron that are present in these two minerals. In this line, the action of gold chloride, silver nitrate and silver sulphate were tried in a qualitative way with both minerals. Of these, the first gave a ready decomposition with both, and produced both ferrous and ferric salts in each case. The silver nitrate gave a similar result. Silver sulphate acted very slowly and without any definite results.

The action of copper sulphate in neutral solution and under pressure was tried with very remarkable results. At the ordinary temperature and pressure the solution of this salt has little effect on either mineral, and the same is true of the solution at a boiling temperature, but under pressure the reaction is complete. The experiment was conducted as follows: 0.2 gram of the finely pulverized mineral was introduced into a stout glass tube, and 50 c.c. of a 10 per cent. solution of the salt, $CuSO_4 \cdot 5H_2O$, added, the air displaced with a pinch of $NaCO_3$ and a drop or two of H_2SO_4 (dilute), and a heavy seal made on the tube. The tubes containing the two minerals were heated for six hours in an autoclave to a temperature of about 200°. The contents of the tubes were found to contain no traces of undecomposed mineral, but there was a black, more or less flocculent precipitate in its place. This proved to be copper sulphide. The solution had not altered appreciably in appearance. The liquid contents of the tube were in each case transferred to a flask previously filled with CO_2 and with 10 c.c. dilute sulphuric acid in the bottom, the tube then rinsed with water and the amount of ferrous iron present titrated with freshly standardized potassium permanganate. In the case of marcasite this gave 18 c.c. $KMnO_4$ solution (this was two- or three-tenths of a cubic centimeter too much, on account of the difficulty in catching the end reaction). To correct this for the iron in the copper sulphate, a blank of 50 c.c. $CuSO_4$ solution, the same as used above with 10 c.c. dilute sulphuric acid, was titrated with the permanganate, giving 0.5 c.c. reduction. The factor of the permanganate was .0054 gm. Fe for 1 c.c. Making the correction for the reduction of 50 c.c. $CuSO_4$ solution, this gives 47.25 per cent. of iron in solution as against 46.67, the theoretical amount in FeS_2. No doubt if the end reaction had been more exact there would have been a still closer correspondence in the result.

The tube containing the pyrite was treated in exactly the same manner, and gave a reduction of permanganate of 3.8 c.c. This time the end

reaction was sharp and exact. Calculating the above to iron (after making correction for $CuSO_4$) this gives 8.91 per cent. of ferrous iron in pyrite. As the total iron is 46.67, this corresponds to 19.09 per cent. of the iron in the mineral, or almost exactly one-fifth. These experiments demonstrate in a positive manner the condition of the iron in the two minerals, and even show the exact amounts of each condition of the iron, ferrous and ferric.*

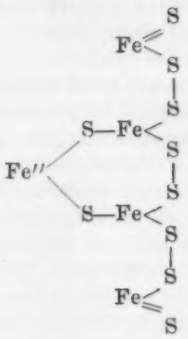
That marcasite should hence be more readily decomposed by oxidation than pyrite seems fully explained by the foregoing investigations, as it consists of $Fe''S_2$, an unsaturated compound. In this compound, sulphur must link to sulphur, or the compound have unsaturated bonds, and hence any element which would attack the sulphur would break up the compound. On the other hand, the iron is held to the sulphur by its full number of bonds, and any substance that has an affinity for iron could not so readily attack it in this condition. This would be true whether ferrous iron be considered here as Fe_2, with a valence of four, or as Fe''. That marcasite is $Fe''S_2$ is also indicated by its oxidation in the air into $FeSO_4$ mainly. Under these same conditions it will be noted that pyrite forms both ferrous and ferric compounds, as $FeSO_4$, but much more $Fe_4O_3(OH)_6$ and free sulphur. Marcasite, however, when decomposed by water under pressure (in nature) forms much limonite also, this being due no doubt to the oxidation being effected under pressure. This constitution explains also the fact that the oxidation of marcasite is continuous and complete, as shown by the current oxidations. It will be shown also that this constitution of pyrite that has been made out explains fully its action with the current. That marcasite is unsaturated is also indicated by the fact that it has not been made artificially or at any rate positively identified in any of the artificial FeS_2 that has thus far been made. If marcasite be a persulphide, as its formula would seem to indicate for a ferrous compound, none of the methods detailed above for making FeS_2 would be applicable in its case, unless perhaps the method of Deville might produce it. All of the other methods would probably produce ferric iron, at least in large part, and the resulting product would be pyrite.

The formula for pyrite derived from my investigations and expressing the relation of the two conditions of the iron in the simplest way is $4\,Fe^{iv}S_2 \cdot Fe''S_2$. This formula is also borne out by what we know of the formation of pyrite as given in the early part of this paper, and by such experiments as I have made on its decomposition, as well as the fact above alluded to that it, in oxidizing in nature, does not form much ferrous compounds but mainly ferric. And it also explains the fact that it is more stable as regards any element attacking its sulphur, for it is most probable that all the sulphur of the $Fe''S_2$ in its formula is linked to iron. I would propose the following structural formula, not as expressing the exact constitution of the compound, for of that we know nothing, but as an

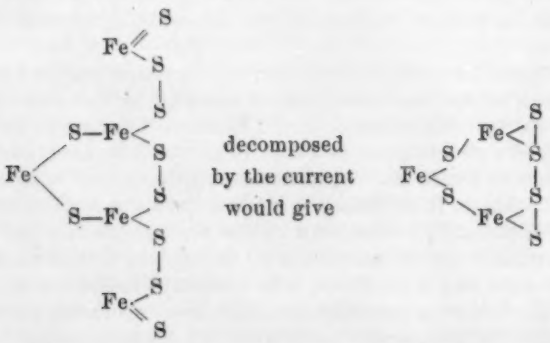
*These results have been confirmed by experiments made during the past year in this laboratory, and not yet published.

expression of the condition of the iron in the molecule and as embodying in a quantitative way the result of my investigations into its constitution. It will be noticed that the sulphur of the $Fe''S_2$ is made to link entirely with iron.

Structural formula of pyrite.



If ferric iron be considered as Fe^{iv}—Fe^{iv} it is only necessary to connect the ferric Fe atoms with bonds, but it seems to me that ferric iron is more likely Fe''', and at any rate this is the simplest way to regard it. A very striking proof of the correctness of the idea expressed in this structural formula that $Fe''S_2$ in pyrite has its sulphur all linked to iron is afforded in the experiments on oxidation of the mineral by means of the electric current as detailed above. It will be recalled that the amount thus oxidized was between 21 and 22 per cent. Now if two molecules of FeS_2 be split off from the above formula, say those linked by sulphur to sulphur there would remain a saturated compound much more difficult to decompose (theoretically) than the pyrite molecule illustrated and the amount of sulphur thus removed would be by calculation 21.33 per cent. This action could be thus illustrated:



Of course this structural formula is only intended to represent the

probable relations of the atoms in the molecule, and the probability that the $Fe''S_2$ is entirely saturated.

A structural formula for marcasite might be given as: and this really expresses our entire knowledge of its constitution. It may be any polymer of this, for being unsaturated it should be capable of forming polymers.

I much regret that want of time has compelled me to discontinue these latter investigations into the decomposibility of these minerals by solutions of metallic salts under pressure, as it seems to open up a way for the study of many other sulphides and would doubtless be productive of most valuable results. Besides this it would probably adduce additional proof of the correctness of my formulas for these minerals as given above.

ACKNOWLEDGMENT.

I take this occasion to express my sense of gratitude to Prof. Edgar F. Smith, who suggested the work to me, and who by his constant encouragement and ready advice has greatly furthered its prosecution. Many of the experiments were made at his suggestion, and no doubt the success of the work is largely due to him.

Notes on the Osteology of Agriochœrus Leidy (Artionyx O. & W.)

By W. B. Scott, College of New Jersey, Princeton.

(*Read before the American Philosophical Society, May 18, 1894.*)

Leidy described this genus more than forty years ago, and yet in spite of the repeated explorations of the White River and John Day beds, it has hitherto been known only from the skull. In 1893, Osborn and Wortman published, under the name of *Artionyx*, an account of an extraordinary hind foot, which, with a typical artiodactyl tarsus, possesses five digits and very large claw-like ungual phalanges. The authors named refer *Artionyx* to the Ancylopoda on account of the resemblance of its phalanges to those of *Chalicotherium*. An examination of the type specimen of the supposed new genus led me to believe that it represented the hind foot of *Agriochœrus* (see Osborn's *Rise of the Mammalia in North America*, p. 44, separatim). This conclusion was founded upon the fact that the tarsus is not only artiodactyl, but characteristically oreodont in structure, and that certain features of the skull and dentition of *Agriochœrus* indicated that it must be an exceedingly aberrant member of the oreodont group.

Mr. J. B. Hatcher, curator of vertebrate paleontology in the Princeton Museum, has just sent me from the White River bad lands of South Dakota three fragmentary skeletons of *Agriochœrus*, associated with

teeth, the examination of which has yielded some very surprising results. Not only is the conjecture confirmed that *Artionyx* and *Agriochœrus* are synonymous names, but also that the forelimb which I described as ? *Mesonyx dakotensis* (*Proc. Acad. Nat. Sci.*, Phila., 1892, p. 306) probably belongs to some nearly allied form. *Agriochœrus* has thus almost as many synonyms as *Chalicotherium*, and as in that animal its various parts have been referred to no less than three mammalian orders, the head to the artiodactyls, the fore foot to the creodonts and the hind foot to the Ancylopoda.

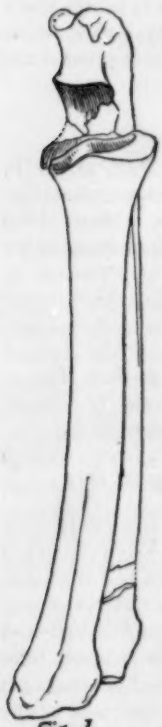


Fig. 1

FIG. 1. Left ulna and radius of *A. major?* ¾ nat. size. The ulna is too much shortened in the drawing.

These preliminary notes will deal only with some of the more salient features of structure, leaving a complete account of the skeleton for another occasion. Beside the three parts of skeletons already mentioned, the material at present available consists of the fore leg and part of manus, lacking ungual phalanges, of the specimen described as ? *Mesonyx dakotensis* (Museum No. 10492), and a second very similar specimen collected last summer by Mr. Hatcher (No. 10695).

The skull of *Agriochœrus* departs very little from that of the oreodonts, even those features in which it differs from the White River members of that family, such as the open orbit and (probably) the absence of the lachrymal pit, being shared by *Protoreodon* of the Uinta Eocene.

The dentition displays the preëminently characteristic feature of the oreodonts in the conversion of the inferior canine into a functional incisor, while $\overline{p.\ 1}$ assumes the form and function of the canine. In other respects the dentition is widely different from that of the oreodonts. Briefly stated, these differences are as follows: (1) The reduction of the upper incisors; (2) the molariform pattern, more or less complete, of p. 4 in both jaws; (3) the structure of the molars, which closely resemble those of *Hyopotamus*, though lacking the protoconule in the upper series. These differences induced Leidy to refer *Agriochœrus* to a family distinct from, but allied to the oreodonts.

The proximal end of the radius is almost exactly like that of *Oreodon;* it is transversely extended, occupying the whole width of the humeral trochlea and antero-posteriorly compressed. The proportions of the three humeral facets are slightly different from those of *Oreodon*, the outer one being relatively narrower and the pit for the intercondylar ridge of the humerus larger and deeper. This applies, however, only to the large species from the upper beds; in *A. antiquus* the correspondence of this por-

tion of the radius with that of *Oreodon* is complete. The shaft has a remarkably strong curvature forward (*i. e.*, with the convexity in front) and is slender with transversely oval section, broadening gradually to the distal end, while in *Oreodon* it continues slender and expands suddenly into the inferior end. The distal portion presents many more points of difference between the two genera than does the proximal and has in *Agriochœrus* quite a deceptively carnivore-like appearance. In the latter it is more thickened transversely and less anteroposteriorly than in *Oreodon*, the scaphoid and lunar facets are less distinctly separated and of different shape and there is no sulcus for the extensor tendons upon the anterior face of the bone. The ulna has an olecranon shaped much like that of *Oreodon* and similarly grooved at the extremity, but decidedly thicker and more massive. The inner humeral facet forms in its distal portion a remarkably prominent flaring lip, far exceeding the corresponding structure in *Oreodon*. The shaft is large throughout; proximally it is trihedral, but soon becomes much compressed laterally and resembles a rib in shape, since the antero-posterior depth is retained. The distal end is contracted to a narrow and simply convex facet for the cuneiform.

The carpus is very different from that of *Oreodon*. A complete account of it cannot yet be given, the only available specimens lacking the scaphoid and pisiform. The lunar is more like that of the Uinta genus *Protoreodon* than that of the White River form. The special peculiarity of the lunar in the true oreodonts lies in its tendency to move over upon the unciform and to make its contact with the magnum altogether lateral. This tendency is already beginning in *Protoreodon* and reaches its culmination in *Merycochœrus* and *Merychyus*. In *Agriochœrus*, on the other hand, this tendency is reversed; the lunar rests almost entirely upon the magnum, its facet for which is broad and but slightly oblique. The anterior portion of this facet is convex, becoming deeply convex behind. The unciform facet is lateral rather than distal in front, but towards the palmar side the unciform extends beneath the lunar. The radial surface is like that of *Oreodon*, but does not descend so low upon the dorsal face of the bone, and the palmar portion does not present so much laterally. The cuneiform is relatively large; proximally it displays a broad concavity for the ulna, while the distal face is occupied by the large subcircular facet for the unciform. The pisiform facet is flat and notably small, whereas in *Oreodon* it is concave and occupies the whole palmar side of the bone. The trapezium is somewhat of a surprise in its shape and connections; it

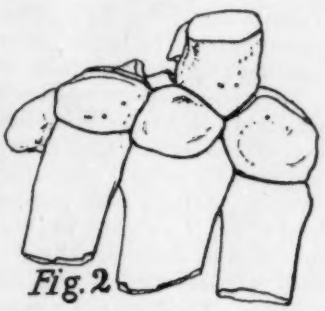


FIG. 2. Part of left manus of *A. major?* Nat. size. The trapezium is incorrectly placed, the surface in contact with the trapezoid being that for the scaphoid.

is a small nodular bone, which is attached to the scaphoid and trapezoid, but has no facet for a first metacarpal. In view of the fact, indicated by Osborn and Wortman, and confirmed by one of the specimens received from Mr. Hatcher, that a hallux was present in the pes, the absence of the pollex, which is preserved in at least two oreodonts, is decidedly unexpected. There is reason to believe, however, that the pollex was retained in *A. antiquus*. The trapezoid is considerably larger than the magnum, especially its dorsal portion ; posteriorly it is excavated on the ulnar side for the extension of the magnum. The surface for the scaphoid is somewhat warped ; broad and proximal in front, narrower and obliquely lateral behind. The distal portion of the trapezoid articulates only with the second metacarpal. The magnum differs from that of *Oreodon* in several important respects. Its proximal surface is occupied principally by the lunar, the scaphoid being confined to a relatively narrow surface in front, though posteriorly the contact is more considerable, and further the magnum has but a very small facet for the second metacarpal. The unciform differs considerably from that of *Oreodon*. Anteriorly the lunar facet forms an excavation upon the radial side of the bone, but posteriorly an almost cylindrical process extends beneath the lunar. The proximal surface, which in *Oreodon* is divided equally between the lunar and cuneiform facets, is occupied almost entirely by the facet for the cuneiform. The articular surface for the fifth metacarpal differs from that of the last-named genus in its larger relative size and more distal position, and the posterior hook of the unciform is decidedly more massive.

The metacarpals are represented by the proximal and distal ends of the second and fourth and by the third complete. They display several significant differences from those of *Oreodon*. As already mentioned, the pollex was probably entirely absent and the other metacarpals are of more uniform size, giving a more isodactyl form of manus than in *Oreodon*. The head of mc. II is slightly smaller than that of mc. IV, and has a large concave facet for the trapezoid and a very minute one for the magnum. The shaft is more rounded and less antero posteriorly compressed than in *Oreodon*. The distal end is creodont rather than ungulate in appearance. This appearance is due to the great enlargement of the processes for attachment of the lateral ligaments, the more distinct constriction of the trochlea and its almost spherical shape and to the greater prominence of the carina. Mc. III is the heaviest of the series ; it bears a large facet for the magnum, which is convex antero-posteriorly and concave transversely, and abuts against the unciform by a process which overlaps the head of mc. IV ; this process is, however, relatively smaller than in *Oreodon*. Mc. IV requires no particular description ; it is rather smaller than mc. III and somewhat larger than mc. II.

The phalanges are, at first sight, very different from those of *Oreodon*, but a careful comparison shows important resemblances, especially if the small species, *A. antiquus*, from the lower beds be considered. In the proximal phalanx the following differences from *Oreodon* may be observed : (1)

The proximal articular surface is more deeply concave, and more oblique to the long axis of the bone, presenting dorsally as well as proximally. (2) The distal trochlea is less depressed, more deeply notched and extends farther upon the palmar side. In the second phalanx the dorso-palmar diameter is relatively much greater and the transverse diameter less than in *Oreodon*. The median ridge of the proximal trochlea is much more prominent and the lateral concavities of this surface more deeply excavated. The distal articular facet is much more extensive, especially upon the palmar side, and more deeply notched in the middle line. The ungual is compressed and forms a large claw, quite unlike the slender pointed hoof of *Oreodon*, though the difference is hardly a fundamental one. The facet for the second phalanx is much greater in the dorso-palmar direction and allows a more extended movement of the two bones upon each other. The mutual relations of the three phalanges is quite different in the two genera; in *Agriochœrus* the arrangement is much like what is found in *Chalicotherium*.

Fig. 3

FIG. 3. Phalanges of IV digit of manus. Same individual as Figs. 1 and 2, nat. size.

The tibia differs in several important respects from that of *Oreodon*. The proximal end is carnivorous rather than ungulate in appearance. This is due partly to the flatness of the condyles and their slighter obliquity from before backward, but especially to the small prominence of the cnemial crest, which though broad and massive is much lower than in *Oreodon*, and hence the proximal portion of the tibia has a decidedly smaller antero-posterior diameter than in that genus; the spine is also less conspicuous. The distal end is remarkable for the great size of the internal malleolus, which is very long and has an articular facet for the astragalus upon its free end.

The tarsus has already been fully described by Osborn and Wortman. It is requisite here, therefore, only to call attention to the differences which obtain between the various species of *Agriochœrus*, as well as between the latter genus and *Oreodon*. In the absence of teeth it cannot yet be determined whether the specimen described by Osborn and Wortman should be referred to any of Leidy's species and therefore, for the purposes of the present comparison, the name *A. gaudryi* O. and W. will be retained. *A. antiquus* from the Oreodon beds differs from *A. gaudryi* in the following particulars: (1) The size is somewhat smaller. (2) All the elements of the tarsus are relatively higher and narrower. (3) There is less difference in size between the internal and external condyles of the astragalus and the latter is separated by a much wider interval from the cuboidal facet. (4) The pit for the internal malleolus is much less deeply

incised. (5) The fibular facet of the calcaneum is higher and more oblique, but less extended antero-posteriorly. (6) The calcaneal facet of the cuboid is relatively broader, while that for the astragalus is narrower. Unfortunately the compound cuneiform is lost from the specimens of *A. antiquus* and the only navicular preserved is too much injured for comparison.

The tarsus of *Agriochœrus* is fundamentally similar to that of *Oreodon*, but with many significant differences of detail. Comparing *O. culbertsoni* with *A. antiquus* the following deviations in the structure of the latter may be observed. (1) All the tarsal bones are much lower and broader. (2) The pit on the astragalus for the tibial malleolus is much deeper and the ridge separating the cuboid and navicular facet of this bone is decidedly more prominent. (3) The sustentaculum of the calcaneum is much more strongly developed and projecting. (4) The calcaneal facet descends lower upon the dorsal face of the cuboid; the hook-like process on the plantar surface of the cuboid is very much more massive and the distal facet for the fifth metatarsal less distinctly separated from that for the fourth. In *A. gaudryi* the plantar hook of the navicular is greatly increased in breadth as compared with that of *O. culbertsoni*, and on the distal surface of the compound cuneiform the facets for the second and third metatarsals lie in the same transverse plane, instead of being at different levels. In consequence of this arrangement the second metatarsal, which in *Oreodon* abuts against the tibial side of the ectocuneiform, is entirely excluded from that element. Whether the same is true of *A. antiquus* cannot at present be determined. In one of the specimens of the latter species the entocuneiform is preserved. It is considerably wider than the same bone in *Oreodon*, and has a distal facet for the first metatarsal, thus confirming Osborn and Wortman's observation as to the presence of a hallux in this genus. A number of caudal vertebræ show that *Agriocchœrus* had a longer and more powerful tail than *Oreodon;* indeed, the tail is quite as well developed as in the larger cats, *e. g.*, the leopard. I have elsewhere called attention to the curious character of the axis in this genus (*Morphologisches Jahrbuch*, Bd. xvi, p. 361). The odontoid process has the characteristic shape found in the oreodonts; it is short and broad, with strongly convex ventral surface, nearly flat dorsal surface, and rounded anterior margin. This process is, therefore, neither conical nor spout-shaped, but intermediate between the two. The neural spine, on the other hand, is entirely different from that of the oreodonts and forms a great hatchet-shaped plate, resembling carnivorous rather than ungulate structure.

The Systematic Position of Agriochœrus.

Leidy separated this genus from the oreodonts, as the type of a distinct family, which he regards as a "peculiar and extinct family of ruminants of the most aberrant character, but allied to the *Oreodonts*." Gill united the two families, giving to *Agriochœrus* subfamily rank, an example which

was followed by Cope and by myself. Osborn and Wortman referred their genus *Artionyx* to the Ancylopoda with *Chalicotherium*, constructing a new suborder, the Artionychia, for its reception. While much remains to be learned regarding *Agriochœrus*, some inferences from the facts of structure described in the preceding pages are reasonably clear. In the first place, I cannot agree with Osborn and Wortman in removing this genus altogether from the Artiodactyla and assigning it to the Ancylopoda. Such a removal implies that all of the artiodactyl features of structure have been independently acquired, and this is highly improbable. I have, it is true, repeatedly insisted upon the reality and frequency of parallelism in development, but it is very easy to push this doctrine to unwarranted extremes. Among mammals, at least, no such extreme case of this mode of evolution is known as would include the skull, dentition, limbs, carpus and tarsus, and in fact everything but the phalanges. The only evidence which could justify such a conclusion would be the finding of a succession of species by which the independent origin of the two groups could be traced out step by step. The agreement of *Agriochœrus* with *Chalicotherium* is of the slightest and most superficial character, consisting only in the fact that both genera have claws. But the ungual phalanges are of a very different pattern in the two genera, and it is surely the less dangerous horn of the dilemma to conclude that this single correspondence is due to parallelism rather than that the numerous and important characters in which *Agriochœrus* agrees with the artiodactyls are the result of such a process.

But a difficulty arises here; is not the distinction between hoof and claw a fundamental one, established long before the artiodactyls had arisen? To answer this question with any certainty would require a much more exact knowledge of the genesis of both kinds of phalanx than we at present possess, but there is much reason to believe that while the ungulate and unguiculate types of mammals are radically distinct, yet the distinction does not rest, as the names imply, upon the character of the unguals. At all events both hoof and claw are found in closely allied genera, as for example, among the rodents, creodonts and edentates. These examples are, it is true, all found among the unguiculates, but there is no *a priori* reason for assuming that a similar diversity among the ungulates may not occur. That it is rare in the latter group is doubtless due to the fact that ungulates almost uniformly employ the feet only for purposes of locomotion, and indeed it is difficult to conjecture what the function of such feet as those of *Agriochœrus* and *Chalicotherium* may have been. In view of all the characteristic artiodactyl structures which *Agriochœrus* displays, one can hardly escape the conclusion that in this case the transition from hoof to claw has actually taken place and that this genus is the culmination of a series of aberrant artiodactyls. In the second place it is obvious that Leidy's separation of *Agriochœrus* from the *Oreodontidæ* is entirely proper. A more obscure problem is to determine the relationship between the two families, and to this end it will be necessary to briefly

recapitulate their resemblances and differences. *Agriochœrus* resembles the oreodonts in the following points: (1) The skull structure of the two families is closely alike and the Uinta genus *Protoreodon* hardly differs at all in this respect from *Agriochœrus*. (2) The very characteristic oreodont features of the caniniform first lower premolar and incisiform canine are repeated in *Agriochœrus*. (3) The atlas and the peculiar odontoid process of the axis are similar in both groups. (4) The elbow joint in the oreodonts is, as is well known, very exceptional among ungulates and all its peculiarities are repeated in somewhat exaggerated form in *Agriochœrus*. (5) The tarsus is oreodont in almost every particular, and is curiously paralleled in many details by that of the Loup Fork genus *Merycochœrus*. It should be remembered in this connection that in *A. antiquus* the tarsus deviates less from the oreodont type than does that of the later and larger *A. gaudryi*, and is in fact intermediate between the two. This is significent, because in the long continued existence of the *Oreodontidæ* from the Uinta to the Loup Fork, there is relatively little change in the tarsus, while each successive genus displays its own particular modification of the carpus. (6) The phalanges, except the unguals, differ relatively little in the two groups and are manifestly of the same type. (7) The articulations of the metapodials are similar.

The most important respects in which *Agriochœrus* differs from the oreodonts are as follows: (1) The pattern of the molar teeth is very distinct, but this gap, especially as regards the lower teeth, is to some extent bridged by *Protoreodon* of the Uinta Eocene, which shows that the two kinds of molar may well have been derived from a single type. (2) The distal end of the radius is creodont, rather than ungulate in character. (3) In *Agriochœrus* the carpus differs decidedly from that of the White River oreodonts, both in the shape and in the connections of its parts, the displacement being in opposite directions. Here again *Protoreodon* tends to connect the two extremes and displays a type of carpus not far removed from that which may have given rise to both. (4) The position of the phalanges with reference to the metapodials and to each other is quite different. (5) Much the most remarkable difference between the two groups is the presence of claws in *Agriochœrus*, while the oredonts have hoofs. (6) Though the large *Agriochœrus* species from the uppermost White River beds has no pollex, there is reason to believe that it was present in the earlier and smaller *A. antiquus*. (7) A striking difference in the knee-joint is observable between *Agriochœrus* and the oreodonts, which indicates that in the former the leg was straighter, while the proximal end of the tibia and distal end of the femur have quite the appearance of the same parts in the Carnivora. (8) All the elements of the tarsus are lower and broader, the astragalus has a deep pit for the internal malleolus and a hallux is present. The latter has not been found in any oreodont. (9) Another carnivorous feature in *Agriochœrus* is the shape assumed by the neural spine of the axis.

In brief, the dentition and skeleton of *Agriochœrus* show a large num-

ber of close correspondences with the oreodonts and especially in those particulars in which that group differs from other artiodactyl families. On the other hand, there are significant deviations from the oreodonts, which are to be found more particularly in the structures correlated with the curious change in foot structure. It seems on the whole highly probable that the two families are not distantly related, especially if the somewhat intermediate character of *Protoreodon* be considered.

The conclusion to which the available evidence leads is, then, that *Agriochœrus* is the last term in a succession of species which form a curiously specialized offshoot of the *Oreodontidæ*, its divergences from that family being principally the results of a change in the functions and uses of the feet. The separation of the two series was probably already established in the Uinta Eocene, for, in spite of its somewhat intermediate character, *Protoreodon* can be a forerunner only of the oreodonts. The Bridger beds may be expected to yield the common ancestor of the two series, and this animal will probably turn out to be a pentadactyl form, with buno-selenodont dentition and quinquetuberculate upper molars, the unpaired lobe in the anterior half of the crown. As I have elsewhere suggested, this hypothetical form may have been already found in the imperfectly known *Helohyus*.

The likeness of the *Agriochœrus* molars to those of *Hyopotamus* has often been noticed and the inference drawn that these two genera were in some manner more or less closely related. Mr. Hatcher writes me that he has lately found feet of *Hyopotamus* which suggest the same affinities. Until this material has been carefully studied, it will be the part of prudence not to prejudge the question.

Three New Methods for the Detection of Forgery.

By Dr. Persifor Frazer.

(*Read before the American Philosophical Society, May 18, 1894.*)

I wish to put on record three new methods which I have applied successfully for the purpose of detecting frauds in written documents.

The first enables one to determine with comparative ease which of two crossing ink lines was made first, and consists in observing the crossing by a lens of low power (four or five diameters) at a very oblique angle. If a light ink line be made over a darker one the appearance to the eye when viewing the crossing perpendicularly to the plane of the paper will be that the darker line is superposed. The reason of this is that ink lines are quite transparent and the darker line is seen through the lighter one and seems to make one continuous line with its two limbs

across the intersection. When the paper is inclined, however, but few of the rays of light which reach the eye by reflexion from the intersection traverse and lose rays by absorption from both ink films; but the greater number penetrate only the upper ink and do not suffer absorption by the lower.

The second is a method of judging whether or not two lines have been made with the same ink and consists in passing over each in succession prisms of red, yellow or blue glass (or two of these), and noting the number of millimeters through which it is necessary to move each prism from the position where its thin edge is in contact with the mark to be judged to that where the color is extinguished and the line is black. The prism is pushed horizontally over the ink mark continually adding to the thickness of the colored glass over the latter. When the line appears quite black the distance in mm. over which the prism has been pushed is read off and compared with the number of mm. which the other line requires to attain the same result. If the inks have the same colors these results must agree.

Third method. In 1886 I read before the Society a paper on the use of composite photography for the purpose of establishing the type of an individual's writing and especially the signature. Since then the mechanical difficulties in the way have been greatly lessened and the method has given most valuable results in cases before various courts. But there are many occasions where it cannot be employed for one reason or another, and in such cases I have devised a system of measurement and tabulation which accomplishes by figures what composite photography established automatically by form. The older method may be called the graphic average of the handwriting and the later the numerical average. The advantage of the former is that it takes into account at once *all* the elements of character, while the latter can deal only with comparatively few, but in spite of this the results attained have been very interesting.

By the system here alluded to a given number of heights, breadths and angles of letters, and spaces between them and between words, are selected and measured in a large number of undisputed signatures. The same elements are then measured in the signature in dispute. The averages of all the elements in the genuine series is then compared with the latter, and their agreement or disagreement will generally lead to a correct judgment as to the genuineness of the disputed signature.

This method has given successful results in a direction which extends the original idea to a study of "guided hands," and it has been possible to extract from the columns of measurements, proofs of the existence of characteristics of each of the separate handwritings.

Stated Meeting, May 4, 1894.

Mr. INGHAM in the Chair.

Minutes of preceding meeting read.

Letters of envoy were received from the Survey of India Department, Calcutta; K. Sächsische Gesellschaft der Wissenschaften, Leipzig, Saxony; Faculté des Sciences, Marseilles, France; Mrs. Carvill Lewis, London, Eng.

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Letters of acknowledgment (144) were received from the Engineers' Club, Franklin Institute, University of Pennsylvania, Mercantile Library, Pennsylvania Historical Society, Free Library of Philadelphia, Academy of Natural Sciences, Wagner Free Institute, Numismatic and Antiquarian Society, Gen. I. J. Wistar, Admiral Macauley, Profs. E. D. Cope, H. D. Gregory, Lewis M. Haupt, H. V. Hilprecht, J. P. Lesley, James MacAlister, Drs. John Ashhurst, Jr., J. Solis Cohen, Persifor Frazer, W. W. Keen, Morris Longstreth, John Marshall, Charles A. Oliver, C. N. Peirce, W. S. W. Ruschenberger, H. Clay Trumbull, W. H. Wahl, Messrs. R. L. Ashhurst, R. Meade Bache, Patterson DuBois, Jacob B. Eckfeldt, Robert P. Field, E. V. d'Invillier, W. W. Jefferis, Franklin Platt, Theodore D. Rand, Louis Vossion, J. M. Wilson, Ellis Yarnall, Philadelphia; Mr. Heber S. Thompson, Pottsville, Pa.; Rev. F.

A. Muhlenberg, Reading, Pa.; Rev. G. W. Anderson, Rosemont, Pa.; Dr. W. H. Appleton, Swarthmore, Pa.; Dr. John Curwen, Warren, Pa.; Mr. Philip P. Sharples, West Chester, Pa.; Wyoming Historical and Geological Society, Wilkesbarre, Pa.; Maryland Institute for the Promotion of the Mechanic Arts, Enoch Pratt Free Library, Baltimore, Md.; Journal of the U. S. Artillery, Fortress Monroe, Va.; Mr. Jedediah Hotchkiss, Staunton, Va.; Leander McCormick Observatory, Library of the University of Virginia, Prof. J. W. Mallet, University of Virginia; Agricultural Experiment Station, Experiment, Ga.; Georgia Historical Society, Savannah; Michigan State Library, Lansing; Athenæum, Columbus, Tenn.; Dr. Robert Peter, Lexington, Ky.; Prof. E. W. Claypole, Akron, O.; University of Cincinnati, Society of Natural History, Cincinnati Observatory, Cincinnati, O.; Oberlin College, Oberlin, O.; Purdue Experiment Station, La Fayette, Ind.; Prof. G. W. Hough, Evanston, Ill.; State Historical Society of Wisconsin, Wisconsin Academy of Science, Arts and Letters, Madison.

Accessions to the Library were reported from Prof. N. A. Cobb, Sydney, Australia; Great Trigonometrical Survey of India, Dehra Dun; Etat Independant du Congo, Brussels, Belgium; Musée Naturelle de Hongrie, Budapest; K. Akademie der Wissenschaften, Vienna, Austria; Gesellschaft für Anthropologie, Ethnologie und Urgeschichte, Berlin, Prussia; Naturwissenschaftliche Verein, Bremen, Germany; Schlesische Botanische Tausch-Verein, Breslau, Prussia; Prof. August Tischner, Leipzig, Saxony; Geographische Gesellschaft, Bern, Switzerland; Société Vaudoise des Sciences Naturelles, Lausanne, Switzerland; Société Francaise de Physique, Paris, France; Mrs. Carvill Lewis, London, Eng.; Geological Society, Glasgow, Scotland; Canadian Institute, Toronto, Canada; American Statistical Association, Prof. Alexander Macfarlane, Boston, Mass.; Prof. C. L. Doolittle, Salem, Mass.; Agricultural Experiment Station, Newark, N. J.; Academy of Natural Sciences, Mercantile Library, Mr. Frederick Prime, Philadelphia; Office of the Chief of Engineers, U. S. Department

of Agriculture, Anthropological Society, U. S. Fish Commission, Census Office, Washington, D. C.; Lick Observatory, Mt. Hamilton, Cal.; Iowa Masonic Library, Cedar Rapids; Geological Survey, Des Moines, Ia.; Deutsche Wissenschaftliche Verein, Santiago de Chile; Sociedad de Ingenieros, Puebla, Mex.

Mr. Henry Carey Baird, in the following letter, presented to the Society, on behalf of the contributors, a handsome portrait of George Ord, a former Vice-President of the Society:

TO THE PRESIDENT OF THE AMERICAN PHILOSOPHICAL SOCIETY:

Mr. President:—The pleasant duty has devolved on me, on behalf of a number of members of the Society, subscribers, of presenting to the Society a portrait of the late George Ord.

This portrait has been copied by Mr. T. Henry Smith from the original by John Nagle, painted in 1829, the property of the Academy of Natural Sciences, to the courtesy of the officers of which institution we are indebted for permission to make this copy.

Mr. Ord was an eminent Philadelphian, having been born here in 1781, and died here January 24, 1866. He was elected a member of this Society October 17, 1817, was Secretary 1820–1827 and also in 1829, Vice-President 1832–1835, Librarian 1842–1848, Treasurer 1842–1847, Councilor 1836. From 1851 to 1858 he was President of the Academy of Natural Sciences. He was also a fellow of the Linnean Society of London.

He was an intimate friend of the naturalist Alexander Wilson, and was his companion in many of his ornithological expeditions. After Wilson's death, in 1813, Mr. Ord completed the eighth volume of Wilson's *Ornithology* (Philadelphia, 1814). In 1825 he prepared a new edition of the last three volumes, and in 1828 published his *Life of Wilson*. In 1834 he wrote the *Memoirs of Thomas Say*, and in 1849 a *Memoir of Charles A. Lesueur*. While his special department was that of natural history and especially ornithology, his labors as a lexicographer were important, having aided in editing Johnson's Dictionary, and having contributed valuable matter to the dictionary of Noah Webster.

It seems eminently fitting that a portrait of this distinguished member of the Society should adorn the walls of its hall, and it is hoped that this faithful reproduction of Nagle's admirable picture may be thought worthy of the subject.

PHILADELPHIA, May 4, 1894. HENRY CAREY BAIRD.

The letter was ordered spread on the minutes with the list of donors.

Dr. Morris moved a vote of thanks to the donors, which was adopted.

Committees on "Membership" and the "Memorial Dinner" reported progress.

A letter was received from Mr. Ben. D. Peter, Lexington, Ky., announcing the death of his father, Dr. Robert Peter, April 26, 1894, æt. 89.

Obituary notice of George de Benneville Keim was read by Dr. Brinton.

Mr. Bache read his views on "The Dynamics of Boxing."

Nomination No. 1273 was read.

Mr. Prime moved and Dr. Brinton seconded the following resolution:

Resolved, That J. Sergeant Price, the Treasurer of the American Philosophical Society, is hereby authorized and directed to cast the vote to which the corporation is entitled as a policy holder and contributor of "The Philadelphia Contributionship for the Insurance of Houses from Loss by Fire," at any election for Directors and Treasurer of the corporation last named, to serve for the year ending the second Monday of April, 1895, and to vote on any questions that may arise at the meeting at which the said election is held.

The resolution was unanimously adopted.

And the Society was adjourned by the presiding member.

Stated Meeting, May 18, 1894.

President FRALEY in the Chair.

Col. Henry DuPont, a newly elected member, was presented to the Chair, and took his seat.

Minutes of meeting May 4th read.

Correspondence was submitted as follows:

Letters of envoy were received from the Institut Egyptien, Cairo; Geological Survey of India, Calcutta; K. K. Astronomisch-meteorologische Observatorium, Triest, Austria; Université de Lyon, Lyon, France; Royal Statistical Society,

London, Eng.; Direction Générale de Statistique, La Plata, S. A.

Letters of acknowledgment were received from the Royal Mint, Melbourne, Australia (139, 140); Académie Hongroise des Sciences, Budapest (135, 136, 137); Schweizerische Naturforschende Gesellschaft, Bern, Switzerland (142); Prof. Giovanni Capellini, Bologna, Italy (142); R. Academia di Scienze, Lettere ed Arti, Padua, Italy (142); Université de Lyon, Lyon, France (130–139, 141).

Letters of acknowledgment (144) were received from the Geological Survey Department, Dr. Alfred R. C. Selwyn, Ottawa, Canada; Literary and Historical Society, Laval University, Hon. J. M. LeMoine, Quebec, Canada; Canadian Institute, Toronto; Society of Natural History, Portland, Me.; Dartmouth College, Prof. Charles H. Hitchcock, Hanover, N. H.; Vermont Historical Society, Montpelier; Rhode Island Historical Society, Providence; Franklin Society, Providence, R. I.; Boston Society of Natural History, Massachusetts Historical Society, Public Library, Mr. Robert C. Winthrop, Boston, Mass.; Museum of Comparative Zöology, Mr. Robert N. Toppan, Prof. J. D. Whitney, Dr. Justin Winsor, Cambridge, Mass.; Free Public Library, New Bedford, Mass.; Essex Institute, Salem, Mass.; American Antiquarian Society, Worcester, Mass.; Mr. George F. Dunning, Farmington, Conn.; Connecticut Historical Society, Hartford; Yale University, Profs. O. C. Marsh, W. D. Whitney, New Haven, Conn.; Agricultural Experiment Station, Storrs, Conn.; State Library, Prof. James Hall, Albany, N. Y.; Buffalo Library, Buffalo, N. Y.; Prof. Edward North, Clinton, N. Y.; Prof. J. M. Hart, Ithaca, N. Y.; Columbia College, N. Y. Academy of Medicine, N. Y. Historical Society, American Museum of Natural History, N. Y. Hospital Library, Prof. Joel A. Allen, Hon. Charles P. Daly, Dr. Daniel Draper, New York, N. Y.; Vassar Brothers' Institute, Poughkeepsie, N. Y.; Geological Society of America, Rochester, N. Y.; Prof. W. Le Conte Stevens, Troy, N. Y.; Oneida Historical Society, Utica, N. Y.; Free Public Library, Jersey City, N. J.; Prof. Robert W.

Rogers, Madison, N. J.; New Jersey Historical Society, Newark, N. J.; Profs. W. Henry Green, Charles W. Shields, C. A. Young, Princeton, N. J.; Dr. Charles B. Dudley, Altoona, Pa.; Dr. Robert H. Alison, Ardmore, Pa.; Prof. M. H. Boyè, Coopersburg, Pa.; Hon. Eckley B. Coxe, Drifton, Pa.; Dr. Traill Green, Prof. J. W. Moore, Rev. Thomas C. Porter, Easton, Pa; Mr. Andrew S. McCreath, Harrisburg, Pa.; Haverford College, Prof. Lyman B. Hall, Haverford, Pa.; Mr. John Fulton, Johnstown, Pa.; Linnean Society, Lancaster, Pa.; Prof. F. A. Genth, Jr., Lansdowne, Pa.; Mr. P. F. Rothermel, Linfield, Pa.; Hon. James T. Mitchell, Prof. Albert A. Smyth, Philadelphia; Philosophical Society, West Chester, Pa.; Col. H. A. DuPont, Wilmington, Del.; U. S. Geological Survey, Surgeon-General's Office, U. S. Coast and Geodetic Survey, Smithsonian Institution, Catholic University, U. S. Weather Bureau, Drs. J. S. Billings, W. J. Hoffman, Col. Garrick Mallery, Prof. Charles A. Schott, Mr. William B. Taylor, Washington, D. C.; University of Tennessee, Knoxville; Texas Academy of Science, Austin; University of California, Prof. Joseph Le Conte, Berkeley, Cal.; Lick Observatory, Mt. Hamilton, Cal.; Prof. George Davidson, San Francisco, Cal.; Academy of Natural Sciences, Davenport, Ia.; State Historical Society, Iowa City, Ia.; Kansas University Quarterly, Lawrence; Nebraska State Historical Society, Agricultural Experiment Station, Lincoln, Neb.; State Agricultural College, Fort Collins, Colo.; Academy of Science, Tacoma, Wash.; University of Wyoming, Laramie; College of Agriculture, Las Cruces, New Mexico.

Letters of acknowledgment for Certificate of Membership were received from Dr. Samuel A. Green, Boston, Mass.; Prof. J. M. Hoppin, New Haven, Conn.; Gen. Isaac J. Wistar, Philadelphia.

Accessions to the Library were reported from the Geological Survey of India, Calcutta; R. Accademia degli Agiati, Roveredo, Tyrol; Osservatorio Astronomico Meteorologico, Triest, Illyria; Université de Lyon, France; Société de Géographie, Toulouse, France; Royal Institution, London, Eng.;

American Oriental Society, New Haven, Conn.; Historical Society, Buffalo, N. Y.; Oneida Historical Society, Utica, N. Y.; Zoölogiçal Society, Editor of the *Naturalist's Leisure Hour*, Indian Rights' Association, Editors of the *International Journal of Ethics*, Prof. E. D. Cope, Dr. Charles A. Oliver, Philadelphia; University of Michigan, Ann Arbor; Observatorio Meteorologico Central de Xalapa, Mexico; Bureau d'Exchanges Internationaux de Publications de la Republique Oriental de l'Uruguay, Montevideo; Agricultural Experiment Stations, Fayetteville, Ark.; La Fayette, Ind.; Brookings, S. Dak.; Tucson, Ariz.

A photograph was received from the Yorkshire Geological and Polytechnic Society, Halifax, Eng., of Mr. James W. Davis, Honorary Secretary.

Council met, and adjourned without business.

The President appointed Dr. Ruschenberger, who accepted, to prepare an obituary of Dr. W. V. Keating.

Mr. Price moved, and Dr. Ruschenberger seconded the motion, to postpone the election of members until next regular time for election, on account of small attendance owing to very stormy weather.

Mr. Lyman read his paper on "Some New Red Horizons."

Dr. Frazer followed with remarks on his own work in the same horizons as illustrated in Adams, York, Lancaster and Cumberland counties in the State.

Prof. Cope read by title a paper from Prof. Scott entitled "Notes on the Osteology of *Agriochœrus* Leidy;" also a paper entitled "On the Lungs of the Ophidia," by himself.

Prof. Barker read a communication entitled, "Comparative Study of the Chemical Behavior of Pyrite and Marcasite," by Amos Peaslee Brown.

Dr. Frazer indicated his method of detecting forgeries in documents and handwriting.

And the meeting was adjourned by the President.